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"Should we build this?": Student reasoning in intentionally facilitated socio-technical design talks

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In pre-college engineering education contexts, detailed explorations of student discourse and teacher moves have begun to emerge. For example, recent studies have shown how particular teacher questions prompt student reasoning during particular phases of the engineering design process (Capobianco, deLisi, & Radloff, 2018) and how a teacher's valuing of heterogeneous ideas sets the stage for students to take epistemic agency in engineering (Carlone, Mercier, & Metzger, 2021). However, important questions remain about how to structure asset-based engineering design conversations in K-8 school classrooms. For example, during whole-class discussion, what prompts can teachers use to elicit a diverse set of student ideas about how a design problem should be defined? How can educators attune students to their peers' differing ideas about why a design prototype failed or succeeded? How can classroom norms for large-group design discussions enable students to take "justice-oriented agency" as they make design decisions (Gunckle & Tolbert, 2018)?

In the "Design Talks" project, funded by the NSF DRK-12 program in the Division of Research on Learning, we seek to explore these questions by enacting and characterizing multiple types of intentionally facilitated, whole-class engineering design conversations in first-grade through sixth-grade classrooms. We are developing case studies of specific types of teacher-supported conversation in which students are asked to consider design decision-making not just as a technical task, but as a complex socio-technical activity with ethical, economic, and political dimensions. Our work foregrounds a perspective of care in students' engineering discourse and builds on emerging frameworks exploring compassionate design, macroethics and ideology, and critical socio-technical literacy (Learning in Places Collaborative, 2020; McGowan, 2018; Philip et al., 2018; Seshadri et al., 2019).

In this paper and its related poster, we summarize our first year of design talk enactments and analysis.

Project Overview

As a team of school-based teacher researchers and university-based researchers, we have organized our collective work around enacting and classifying different genres of whole-class design talks that support students' knowledge building and socio-ethical reasoning in engineering. Table 1 identifies the different genres that we explored in the project's first year and provides examples of design talk topics from the teacher researchers' classrooms. In the first year, the design talks took place in two sixth-grade classrooms in the northeastern United States. Teachers of younger grade levels have since joined the project team, and future work will feature a wider range of elementary grade levels.

Table 1. Whole-class engineering design conversations representing different Design Talk genres

Genre of Design Talks	*Talk Description*	*Learning Goals*	*Example*
Problem-Scoping Talks	Talks that negotiate the criteria and constraints for solving a design problem	● SWBAT identify design criteria and constraints considering the physical and situational conditions, perspective of involved parties, and values/ethical orientations.	*What criteria tell us what the design needs to do or needs to have?*
Should-we/ Impact Talks	Talks that reflect on the different perspectives and relationships of those who may be impacted by a design	● SWBAT identify multiple stakeholders and hypothesize their perspectives ● SWBAT make connections between how multiple stakeholders' perspectives might be in conflict, or in alignment ● SWBAT notice anthropocentric, and Western ideological orientations of perception ● SWBAT notice histories, processes, and/or relations of power.[1]	*Who and what is affected by the building of a telescope?*
Ideation or Brainstorming Talks	Talks that elicit multiple ways of solving a problem	● SWBAT identify multiple and distinct possible solutions to a problem ● SWBAT engage in divergent and creative thinking	*How could the ancient Mesopotamians water their crops from the far away river during the dry months and protect their farms/cities during floods?*
Design-in-Progress Talks	Talks that support reflection on students' building, testing, and iterating of artifacts	● SWBAT express ideas about why a design performed as it did and what its performance means for the next iteration ● SWBAT describe similarities and differences in data collected from multiple designs ● SWBAT evaluate arguments in favor of and against specific designs within the established evaluation context	*Why are these wind turbines performing this way? What should their designers change about them?*
Design Synthesis Talks	Talks that ask students to reason about multiple designs and synthesize common themes	● SWBAT identify features of a design and offer hypotheses about their function ● SWBAT describe how a singular component fits within a wider system (move back and forth between a component- and systems-perspective)	*Many of the things we have around the house have moving parts that have to work together in order to work. Your job today is to communicate how you think a common household item works using pictures and words.*

[1] We draw from Philip and Gupta's (2020) framing of power to mean "the ability to alter or maintain the physical, social, structural, cultural, and political conditions, resources, and/or opportunities of individuals and collectives"(p. 197).

Analytical Approach

To date, we have focused our data analysis work on developing two interpretive case studies (Merriam, 1998), each focused on one genre of design talks. The first is focused on "should we?" design talks, and the second is focused on "problem-scoping" design talks. Overall, as we analyze students' and student-teacher interactions in the design talks, we draw on qualitative discourse analysis techniques (Bloome, Carter, Christian, Otto, & Shuart-Faris, 2004; Erickson, 1992; Lemke, 2012) to analyze classroom audio recordings and classroom artifact data. We are guided by two research questions: *(1) What are productive ways to frame and prompt whole-class engineering design conversations that include reasoning in the socio-ethical domain? (2) What reasoning practices do students employ as they consider both design problems and design solutions in these conversations?*

Below, we summarize each case study to demonstrate how the Design Talk project is attuning our teacher-researcher project team to the ways that students negotiate power and relationality in whole-class engineering design conversations.

Case Study 1: "Should we?" Design Talks

The "should we?" talks case study focuses on two sixth-grade classroom discussions conducted during virtual schooling when collaborative hands-on engineering design was not feasible. Two different teachers from our teacher-researcher project team led these design talks. Both began on Zoom with an introduction to a real large-scale technological design. In one class, students read a news article about a ground-based telescope proposed for Mauna Kea, a technology related to their science curriculum on the earth-moon-sun system. In the other class, at a different school, students viewed a video about a proposal for an agricultural dam in the Amazon rainforest. This technology was related to their social studies curriculum on the features of different societies.

After learning about the proposed designs, the students responded synchronously on a collaborative virtual whiteboard (a Jamboard; see Figure 1) to specific prompts related to the overarching question of whether the technology should be constructed. In the Mauna Kea telescope design talk, the prompt was, "If this is a story, who are the characters? Make a list of who or what is being impacted by the building of the new telescope." In the Amazon dam design talk, the prompt was, "What are the pros and cons to building a dam and farms in the Amazon rainforest?"

After these "should we?" design talks were enacted, we conducted qualitative analysis of students' Jamboard and virtual chat postings and of notes from our project team meetings. We drew on open coding and concept coding (Saldaña, 2016) to generate themes describing (1) the teacher-researcher team's reasoning about the design talk prompts and (2) the socio-ethical reasoning practices achieved by students.

Reasoning about "Should-We?" Design Talk Prompts. In working to design the prompts as a teacher-researcher team, three principles emerged for framing design talks in the "should we?" genre. First, we *centered the talks on real places and events related to the classroom curriculum*. These conversations were embedded in larger units on space science and society complexity,

respectively, and the team saw opportunities to invite multiple (including more critical) perspectives on the role and values of scientific and engineering designs. We chose technological design scenarios that had been covered in the popular press and that took place in geographical locations of interest to the students. Second, we *selected resource texts that featured multiple differing views on the technological design*. The article that students read to prepare for the telescope talk included quotations not only from astronomers supporting the project and native Hawaiians opposing the project, but also from government representatives, educators, and farmers. The video that students viewed before the Amazon dam talk also included voices from both dominant and non-dominant groups in the local society. Third, we *posed prompts that would allow for students to consider multiple perspectives and relationships to the design decisions*. In the telescope example, the teacher framed the conversation by tapping into stories as a genre, inviting students to consider characters, relationships between characters, and critically consider the impact of the telescope. This prompt invited students to not just consider a particular client or even stakeholders, but to consider multiple relationships.

Figure 1. Jamboards from the "Should we?" design talk activities in two sixth-grade classrooms

Students' Socio-Ethical Reasoning Practices. In looking at student responses to the "should-we?" design talk prompts, we found that within the Jamboard posts in both contexts (Figure 1), the sixth-grade students reasoned carefully about the impacts of potential large-scale technological designs on multiple stakeholders. They thought expansively about the members of the community who would experience the effects of this decision, and they pointed out the consequences of the technologies on more-than-human characters such as animals and the land. Students also collaborated with each other as they engaged in socio-ethical reasoning about the designs. Their posts made references to each other's ideas and used symbols to show connections from a design consequence identified by one student to a consequence suggested by another.

In attending to the ways that students reasoned collaboratively about power and relationality in the telescope and dam design contexts, we saw two main themes emerge: negotiation of who has power, and differentiation between having a voice in the design outcome and having a right to decide the outcome. One student's Jamboard posting focused on rights and power as the student considered the people of Hawaii:

> *"The people of Hawaii are the main characters in the story. They are in impact of the telescope because it is being built on a sacred place. They do not want a huge telescope on a place they love because in it special to them. Building that telescope would be like someone built a mall in your backyard. Your backyard is yours. People don't have the power to build a mall where you live! That is how the Hawaiians feel."*

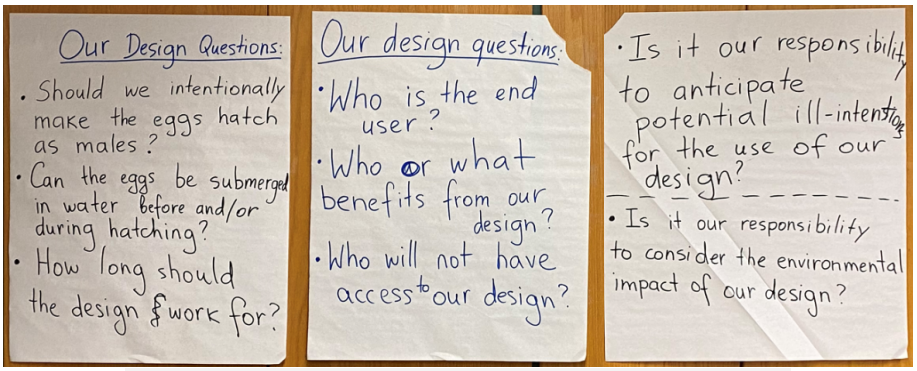
Students go beyond identification and perspective taking of characters involved in this plot, to construct notions of "rights holders" - a positionality that comes with entitlements to decide what happens in your space. This is an inherently political orientation, integrated into students' design thinking as they push back against the notion that a design framed as a "public good" could supersede the sovereignty of Native Hawaiians. The undercurrent of the framing of this design as a "public good" ascribes a neutrality that obscures the political stakes.

Case Study 2: "Problem-Scoping" Design Talks

The data for the case study on "problem-scoping" design talks come from an audio-recorded sixth-grade classroom discussion at the beginning of a curriculum module on the design of temperature-regulated turtle egg protectors. In this talk, the students were collectively establishing the criteria and constraints for this engineering design problem, which was adapted from the OpenSciEd Unit 7.2 (OpenSciEd, 2022). The teacher posed this problem as the culminating task of their multi-week science unit on chemical reactions.

The design problem centered on the challenge of transporting sea turtle eggs found abandoned after a hurricane to a conservation center. Student groups built and tested insulated transport devices to keep the eggs at the optimal temperature and protect eggs from breaking during transport. The teacher dictated using a chemical reaction for the heating element to align with previous course content; students decided to use common household materials for constructing their devices.

On day 2 of the unit, the teacher facilitated a whole-class problem-scoping design talk to define the scope of the design problem, including deciding on criteria and constraints for their devices and defining the intended user. Figure 2 shows the anchor charts created by the teacher during this discussion.



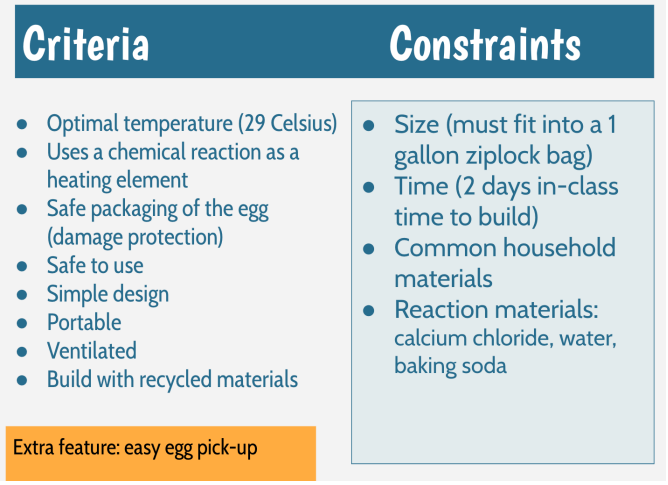


Figure 2. Anchor charts constructed by the teacher to record student ideas and questions during the egg protector problem-scoping talk. The criteria and constraints were transcribed by the teacher onto a slide for the following class period.

We audio-recorded and transcribed the whole-class problem-scoping talk. To analyze students socio-ethical reasoning practices, we are drawing on the discourse analysis approaches of interaction analysis and structural-textural analysis (Lemke, 2012). Preliminary analysis of the problem-scoping design talk suggests the following themes.

Within this conversation, the teacher's push for students to consider a possible user for the design surfaced multiple students' concerns about possible unintended consequences. In particular, students seemed to link design outcomes *with* interactionally constructed "profiles" of different types of users. For these students, it was not a question of whether or not they should help the turtles, but how and by whom should that help be provided.

For example, students built on each others' contributions in constructing the notion of an "average" person's encounter with the turtle eggs versus possible outcomes from a "scientific expert." In this conversation, students' reasoning about a possible user was not without a

consideration of the ways in which this user's intentions, motivation, and background knowledge could impact the outcome for the turtle eggs. Students' reasoning about intentions, motivation and background knowledge was sociopolitically situated as well - the threat of an "average" person without professional commitments or personal connections to the egg could lead to selling the egg for profit. The construction of these possible user profiles was productive for anticipating possible consequences by situating the engineering design within a broader "use case." This process was rife with tensions as students' agreement and disagreement with voiced positions was audible throughout the classroom conversation.

Next Steps and Contributions

Development and enactment of design talk activities is ongoing. Our next steps include further analysis of *should-we* and *problem-scoping* design talks as well as enactment of design talks at different elementary grade levels and of different genres, including *ideation*, *design-in-progress*, and *design synthesis*.

This project is contributing to emerging research on classroom discourse in pre-college engineering education. It is advancing knowledge on the genres of whole-class engineering design conversations that can foster students' knowledge building and socio-ethical reasoning. These contributions will help teachers of engineering facilitate more meaningful engineering design activities that go beyond supporting students to move through the engineering design process, toward helping them make meaning about the problems, mechanisms, and social, ethical, economic, and political dimensions of engineering design. This research also has the potential to shed important new light on how K-6 classroom engineering talk can attend to systems and history to frame both problems of pedagogy and design.

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