Design Talks: Whole-Class Conversations during Engineering Design Units

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Abstract

Teacher-facilitated whole-class conversations can help elementary students apply the full power of the NGSS science and engineering practices to an engineering design process. In this article we describe and provide examples for five kinds of Design Talks. Each type of Design Talk centers on a different framing question and is facilitated by specific prompts that help students voice their ideas and make connections to others' ideas. Problem-Scoping Talks provide opportunities for students to identify and scope design problems (NGSS Practice 1) with multiple technical, material, and social considerations. Idea Generation Talks help a whole class collectively generate many design ideas (NGSS Practice 6). Design-in-Progress Talks help students express ideas about why a design performed as it did and consider what its performance means for their next iteration (NGSS Practices 2 and 4). Design Synthesis Talks support students to reason across these designs and synthesize common themes (NGSS Practices 2 and 4). Impact Talks invite students to consider questions like, "should we design this?", and "who might this solution benefit and who might it harm?" (NGSS Practices 1 and 8). Teachers can implement Design Talks to invite and leverage different student strengths in engineering design, with particular attention to issues of equity and care.

In a typical engineering unit in an elementary classroom, you would likely see students working together to construct a prototype, huddled over their design plans, or testing their solutions. Ideally, these opportunities provide an exciting context for students to engage in the NGSS practices, particularly defining problems, developing and using models, analyzing and interpreting data, and engaging in argument from evidence. However, in reality, it can be challenging for a small group of students on their own to apply the full power of these practices to an engineering design process. We propose that intentionally planned, teacher-facilitated whole-class conversations—what we call "Design Talks"—can help.

Inspired by prior work on classroom talk in math and science education (e.g., Michaels & O'Connor, 2012; Smith & Stein, 2011), our team of 1st-6th-grade teachers and university researchers have been developing and enacting Design Talks to strengthen how student engineers engage in practices of science and engineering, with particular attention to issues of equity. With teacher facilitation, Design Talks can invite and leverage different student strengths in engineering design. These conversations also offer opportunities to consider a perspective of care (Gunckel & Tolbert, 2018) in engineering, making space for students to reflect on questions like "who might benefit from a design and who might be harmed?" In this way, Design Talks not only connect to the NGSS practices but also provide opportunities to connect engineering to other subjects, such as language arts and social studies. Below we describe and provide examples for five kinds of Design Talks that our team has explored (Table 1).

Table 1. Design Talks are whole-class conversations that can connect students' engineering design work to NGSS practice standards.

Design Talk	Framing question	NGSS Practice Standards
Problem-Scoping Talks	What do we need to consider to solve this problem? What would count as a solution?	1. Asking questions and defining problems
Idea Generation Talks	What are multiple possibilities for solving the problem?	6. Constructing explanations and designing solutions
Design-In-Progress Talks	Why did a design perform as it did? What features should we change?	2. Developing and using models; 4. Analyzing and interpreting data; 7. Engaging in argument from evidence
Design Synthesis Talks	What are similarities and differences in our designs? What can we learn from these patterns?	2. Developing and using models; 4. Analyzing and interpreting data; 7. Engaging in argument from evidence
Impact Talks	Should we design this? Who and what will be impacted by our design?	1. Asking questions and defining problems; 8. Obtaining, evaluating, and communicating information

Design Talk #1: Problem-Scoping Talks

Problem-Scoping Talks provide opportunities for students to identify and scope design problems (NGSS Practice 1), which are often messy and ill-defined, with multiple technical, material, and social considerations. In one Problem-Scoping Design Talk in our project, the teacher, Vera, led a whole-class conversation on the problem of designing insulated devices to protect abandoned sea turtle eggs at the optimal temperature for transport to a conservation center (NGSS 5-PS1-3) (Hereau et al., 2021). After introducing the task, Vera asked students, "What criteria and constraints should you consider when designing and testing prototypes in our classroom?" After students talked in small groups, she led a whole-class conversation scoping their design problem. Students first brought up technical criteria, such as temperature, size, and protection from damage. Students then considered the social dimensions of the design problem, reflecting on how a user's intentions, motivations, and background knowledge could impact the outcome for the eggs. Some students advocated that "it shouldn't have to be used by like some technical genius" and others shared questions about whether "regular people" would accidentally hurt the eggs, misuse their device, or exploit the eggs for profit. The teacher reframed these concerns as questions for groups to consider (Figure 1). This conversation offered opportunities for students to scope the broader ethical and political contexts of sea turtle egg protection.

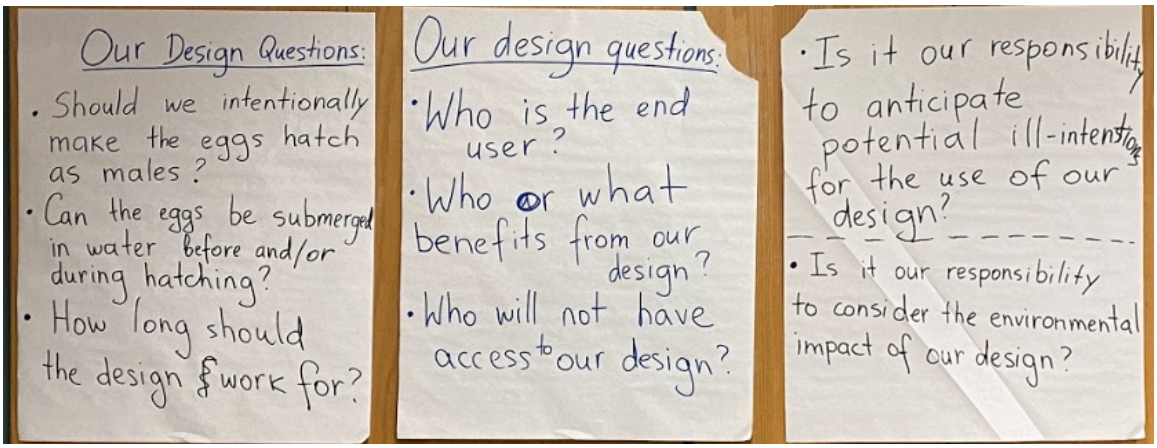

Figure 1. During a Problem Scoping talk, students generated questions to help them determine what would be considered a successful solution to a sea turtle egg protection design problem.

Problem-Scoping Talks help students name the things they need to attend to in a problem and consider what will count as a solution. Further, these talks prompt students to reflect on what perspectives and communities need to be involved in addressing problems. They can foster rich conversations not just about identifying technical criteria and constraints, but also about the values and ethics to prioritize in their designs.

Design Talk #2: Idea Generation Talks

Idea Generation Talks show how a whole class can collectively generate many design ideas. In these talks, students share their ideas for how to solve a design problem, have opportunities to hear lots of different ideas, and build off each other's contributions (NGSS Practice 6). For example, Molly posed to her students the problem of Kindergarteners having a difficult time using a particular monkey bar structure on the school playground. To address the NGSS standard related to mimicking plant and animal parts (1-LS1-1), Molly suggested the students try a biomimetic design approach to think of possible solutions. Displaying a collage of photos of animals and plants that excel at climbing, reaching, sticking, jumping, etc., she invited students to brainstorm: "these pictures of some plants and animals might give you some ideas of what we could design for the Kindergarteners to help them play on that play structure. What are you noticing?"

In the resulting conversation, the students shared a wide range of ideas. The first three students suggested gloves with strong straps as sticky as a gecko's toes, attachments for shoes that would enable jumping like a frog, and stretchy gloves that would let you glide like a flying squirrel. The next student connected these ideas by noting that if the jumping shoes gave the Kindergartener too much motion, the sticky gloves could help them stick to the monkey bars once they got there. Another student suggested adding a switch that could block some of the sticky sections when you wanted to swing to a new bar (Figure 2). As the conversation continued, students brainstormed more design solutions, clarifying, refining, and combining ideas together. With teacher facilitation, Idea Generation talks can help one student's idea spark new ideas with other students, and moving forward, the whole-class conversation can fuel individual students' future thinking.

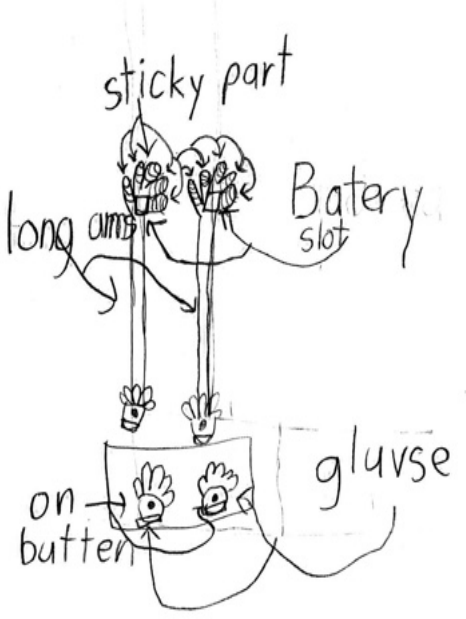

Figure 2. After an Idea Generation talk, a student integrated the ideas shared by multiple classmates into his design sketch for a monkey bar helper device.

Design Talk #3: Design-in-Progress Talks

Design-in-Progress Talks can help students express ideas about why a design performed as it did, consider what its performance means for their next iteration, and recognize that designs are tested and refined (NGSS Practices 2 and 4). For instance, Rae led a Design Talk around the performance of students' wind turbine prototypes (NGSS 4-PS3-4). The previous day, Rae had noticed that students focused primarily on how the weight of the turbine blades impacted the speed. Giving limited attention to other design parameters, the students concluded that lighter blades always resulted in faster spinning. Rae organized the conversation by asking the class to study the performance of one group's wind turbine. Rae made an intentional choice in selecting the prototype to observe—it was the only artifact that had holes cut out of its blades. The blades were lighter, so students expected it would spin quickly, but it did not. In response, the students reasoned about the surprising performance of this one prototype. They generated new ideas about parameters they could vary in their next round of design, including blade rigidity and shape.

Design-in-Progress talks offer opportunities for students to evaluate arguments in favor of or against specific design features (NGSS Practice 7). These conversations push students to move beyond "show-and-tell" of their own design, and even beyond sharing what they like or would change about their peers' design, to think together about the mechanisms of individual designs.

Design Talk #4: Design Synthesis Talks

After students create and test a range of design solutions, Design Synthesis Talks can help them reason across these designs and synthesize common themes (NGSS Practices 2 and 4). These talks can help students compare and contrast across designs intended to solve the same problem.

Sometimes students' solutions are designed to accomplish the same function but with different structures. In one Design Synthesis Talk, Naina asked her students to think about all the prototypes they had seen over two cycles of building and testing model storm drain filters in bins with "polluted" water (NGSS 5-ESS3-1). She asked: "What is something in your own model *or in somebody else's* that you think worked very well?" Multiple students pointed out that the designs that used cotton rounds successfully filtered almost all the oil out of the water. They drew on evidence from their observations (NGSS Practice 7) to contrast the ways different designs positioned the cotton to absorb the oil while still allowing the water to flow through easily.

Design Synthesis Talks can also help students build a more nuanced understanding of a design problem by noticing differences in how their peers interpreted criteria and constraints and tackled the problem overall. For example, Molly led a Design Synthesis talk about the range of ideas students had generated for designs that would help Kindergarten students at their school use the monkey bar structure more easily (NGSS 1-LS1-1). After each student displayed their sketch and briefly described their idea to the rest of the group, Molly asked the class to think about how they might summarize the set of ideas into four or five "big ideas" to tell the Kindergarteners. Students pointed out that one group of ideas prioritized sticking to the monkey bars, another group focused on reaching farther, and another group focused on jumping. These

categories reflected not just different design parameters but altogether different functions for playing on the monkey bars. Molly wrote these categories across the top of the white board, and each student considered the main function of their idea and posted it to the best category (Figure 3).

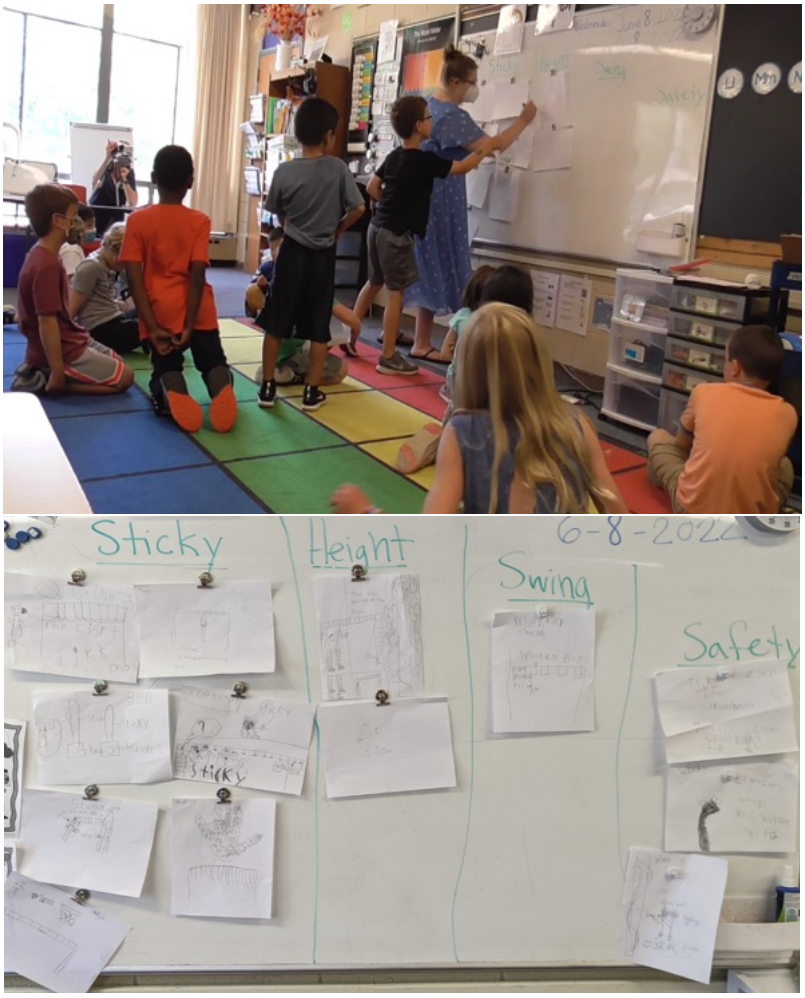

Figure 3. In a Design Synthesis talk, students reflect on the main function carried out by each proposed design for a monkey bar helper device.

Design Talk #5: Impact Talks

Impact Talks invite students to consider questions like, “should we design this?”, “what are the human and environmental consequences of considering this issue as an engineering design problem?”, or “who might this solution benefit and who might it harm?”

Vera led an Impact Design Talk during a unit on the solar system, asking students to read about and consider the decision to build the Thirty Meter Telescope on Mauna Kea, a sacred mountain to Native Hawaiians. To frame this conversation, which took place online during the 2020-21 school year, Vera asked students to consider who were the characters involved in this decision,

what were the relationships between characters, and what might be the impact of the telescope. Using a digital white board, students named characters such as the scientists, the Native Hawaiians, protestors, and even the mountain itself. Students considered who has power in the relationships between the characters and whose rights were impacted by the decision. One student wrote: "I don't think they should build [the telescope] there, because it is a sacred space for [Native Hawaiians]. I would be like building a telescope on top of a church." To make sense of the perspective of the Native Hawaiians, this student made connections to her own cultural values, seeing parallels in the sacred spiritual place of the mountain with a church. Throughout the conversation, the students not only considered who might be impacted by the design, but also reflected on who should have power to make this decision and whose rights are at risk. Importantly, the students had opportunities to foreground Native sovereignty rather than accept that an engineering or scientific design's benefits superseded this.

If we frame engineering design only as a universal force for good in a "march toward progress," we might overlook concerns about how engineering can help replicate or disrupt injustices in local and global contexts (Gunckel & Tolbert, 2018). Impact Talks play a valuable role in helping students articulate social, ethical, and moral dimensions of engineering design, including to consider whether to implement an engineering design, who needs to have a voice in determining a solution, and what might be unintended consequences of a design. As seen in Vera's Impact Talk, students need to draw on diverse sources of information and different perspectives to consider the impact of potential design solutions (NGSS Practice 8).

Conclusion

We have described five kinds of whole-class Design Talks in which students participated as a classroom community in key practices of science and engineering to deepen their reasoning about design problems, prototypes, and impacts. Each kind of Design Talk centered on a different framing question (Table 1) and was intentionally facilitated by a teacher with prompts to help students voice their ideas and make connections to others' ideas (Table 2).

By using Design Talks in their classrooms and tailoring each Design Talk to a specific purpose, such as Problem Scoping, Idea Generation, Design-in-Progress, Design Synthesis, or Impact, teachers can help students collectively connect the NGSS practices to an engineering design experience in a way that highlights different student strengths and that makes space for socioethical reasoning about how society and technology interact.

Table 2. Sample teacher prompts for starting each Design Talk

Design Talk	Sample Teacher Prompts
Problem-Scoping Talks	Whose perspectives should we consider in solving this problem? What does our solution have to have to be successful? What are our constraints do we have in designing our solutions?
Idea Generation Talks	What ideas do you have for solving the design problem? How might different solution ideas work together?

Design-In-Progress Talks	What problems did you encounter in building or testing your designs? (Select a particular prototype) What do you notice about this design? Why do you think it performs in this way? What changes should we make to our designs to make them more successful?
Design Synthesis Talks	What is something in your design or in somebody else's that you think worked very well? What do you notice across the different design solutions? What are different categories of solutions?
Impact Talks	If we designed this solution, what might happen? Who might benefit and who might be harmed? Should we implement this design solution? Why or why not?

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