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The Role of Whole-Class Conversations in Supporting Early Elementary Students' Engineering Design Sense-Making

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Abstract: We consider how intentionally planned and facilitated whole-class conversations can "make space" for students' sense-making about engineering problems and solutions and position them with epistemic authority to contribute to collective thinking. We conducted a case study on a first-grade engineering lesson that included whole-class Idea Generation and Design Synthesis Talks. We found students sense-making as they refined their design proposals and analyses in light of classmates' contributions to the whole-class conversations.

Introduction

For elementary students, the task of constructing an artifact for an engineering design challenge offers an opportunity to construct knowledge. As they design solutions to problems, students can build knowledge about how designed systems work, how they interact with the natural world, and how they influence people and society. However, for engineering design experiences to be sites of knowledge building, students need support to engage in *sense-making*, both individually and collectively. Sense-making involves developing understandings of the world through generating, using, and refining one's ideas in interaction with other people, representations, tools, and objects (Schwarz et al., 2020). In this paper we consider how Design Talks—intentionally planned and facilitated whole-class conversations that can be incorporated in engineering design lessons—can "make space" for students' sense-making about engineering problems and solutions and position them with epistemic authority to contribute to the class's collective thinking (Engle & Conant, 2002; Haverly et al., 2020).

With a team of elementary teachers and engineering education researchers, we have been exploring five different kinds of Design Talks. Here we focus on a case where a teacher implemented two Design Talks within a lesson—Idea Generation and Design Synthesis Talks. We ask: *How did these Design Talks make space for early elementary students to participate in sense-making about engineering designs?*

Table 1
Design Talks are whole-class conversations that can connect students' engineering design work to NGSS practice standards (talks need not be implemented sequentially)

	Framing Question	Sample Teacher Prompts
Impact	Should we design this? Who and what will be impacted?	If we designed this solution, what might happen?
Problem-Scoping	What do we need to consider to solve this problem?	Whose perspectives should we consider in solving this problem?
Idea Generation	What are multiple possibilities for solving the problem?	What ideas do you have for solving the design problem?
Design-In-Progress	Why did a design perform as it did? What features should we change?	Why do you think this device performs in this way?
Design Synthesis	What are similarities and differences in our designs? What can we learn from these patterns?	What are different categories of solutions?

Data collection and analytical framework

This qualitative descriptive case study comes from a first-grade engineering design lesson on designing a tool to help Kindergarteners more easily use the monkey bars. The lesson took place at a suburban elementary school in the northeastern U.S. during a curriculum unit on plant and animal structure and function. Researchers video recorded all large-group talk among the class of 14 students and all small-group interactions of one focal group of students. We selected this lesson's two Design Talks for further study after we noticed that multiple students were offering contributions and that multiple ideas were at play in the space; we also were interested in these conversations given that they involved the youngest learners in our project.

In conducting this research, we were grounded in the perspective that learning engineering involves increasing participation in its disciplinary practices. To look for evidence of the practice of sense-making, we drew on the notion of epistemic authority (Carlone, Mercier, & Metzger; 2021; Engle & Conant, 2002). We explored when and how students exercised authority to make contributions to the class's collective thinking.

Findings

The lesson opened with an Idea Generation Talk that offered opportunities for students to brainstorm multiple solutions to the problem. The teacher, Ms. M, began the talk by displaying a photo collage of plants and animals that excel at vertical movement and inviting her students to brainstorm: "So we want to design something to help kindergarteners be able to use [the monkey bar] structure. These pictures of some plants and animals might give you some ideas of what we could design. What are you noticing?" In the resulting 10-minute large-group conversation, 12 of the 14 students voiced contributions and connections. Defying the stereotype that first graders fixate on their own ideas, these students worked with a wide range of design ideas, refining both their own and others' ideas as the conversation evolved. The first five students to propose ideas suggested gloves and shoes with special features for jumping, stretching, and sticking. Then, showing epistemic authority to evaluate and refine the community's ideas, a sixth student noticed that if the tool was "too sticky, they can't, what if they can't swing?" Ms. M valued this different way of contributing, pointing out a new problem nested within the solutions proposed so far, and invited more thoughts. Additional students weighed in with new designs that had features to decrease stickiness or detach once the Kindergartener was ready to swing to a new bar. For instance: "when you're about to swing, there's these little slots, that keep out a couple more of those things, so then you can swing a little better."

After students drew individual sketches of their design ideas, the teacher facilitated a Design Synthesis Talk. She asked each student to display their sketch and briefly describe their idea to the group. Then she asked the class 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. Ms. M wrote these categories across the top of the white board, and each student considered the main function of their idea and posted their sketch under what they thought was the best heading. Some students saw that their design had characteristics of several categories, and they asked for advice from classmates. This realization of a difficult choice and request for help from other students showed that they saw their peers as having authority to contribute to the class's work. Thus, in this Talk, we observed that students were positioned with epistemic authority to identify common themes across their solutions and advise each other on how to classify different solutions.

Conclusion

In this case study we found first graders engaging in serious engineering design thinking during two Design Talks where they collaboratively generated and then compared ideas. Initiated by carefully framed open-ended prompts and sustained by Ms. M's responsive facilitation moves, the Design Talks were participation structures that enabled nearly all the students to author themselves as contributors to the class's knowledge about possible structures and functions that might solve the kindergarteners' monkey bar problem. These findings highlight the promise of Design Talks for making space for students' shared sense-making in engineering.

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