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# Teachers' Perspectives on Facilitating Design Talks with Young Learners (Fundamental)

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## Introduction

Building from extensive work on classroom discourse in science and math education (e.g., Michaels & O'Connor, 2012; Parrish, 2011), a growing body of work in pre-college engineering education characterizes *engineering classroom talk* and its influence on students' learning. For instance, researchers studying elementary school engineering have shown how particular teacher questions cue student reasoning during different phases of the design process (Capobianco et al., 2018) and how teachers' recognition of disparate student ideas helps students take agency as designers (Carlone et al., 2021).

One form of classroom talk is the whole-class conversation, which can be an important site for growth in students' ideas and disciplinary ways of thinking, including ideas and ways of thinking about engineering design problems and solutions. With intentional teacher facilitation, whole-class conversations can help students refine their engineering reasoning, consider new ideas, and make new connections between different ways of defining or solving a problem. Participating in whole-class conversations during engineering design experiences can also help students expand their engineering thinking to include perspectives of care (McGowan & Bell, 2020) and socio-ethical deliberations.

In a multi-year collaboration of university researchers and classroom teachers in first- through sixth-grade classrooms, we have been enacting and studying five different types of whole-class engineering design conversations, which we refer to as Design Talks. Examples, including video clips and transcripts, can be found on the project website at www.engineeringdesigntalks.org and in prior publications (Wendell et al., 2024; Wendell, Watkins, Andrews, & Malinowski, 2023; Wendell et al., 2022).

As a teacher-researcher community of practice, our process has involved the collaborative planning, implementing, video recording, and de-briefing of over 40 Design Talks. This process has helped us explore a range of questions about how to structure Design Talks, such as, What prompts can teachers use to elicit a diverse set of student ideas about design problems? How can educators attune students to their peers' differing ideas about why a design prototype failed or succeeded? How can classroom norms enable students to center justice and care as they make design decisions?

Our prior analyses of Design Talks have focused on the details of specific implementations and on the practices of science and engineering that they support (Wendell et al., 2023; Wendell et al., 2022). We have not yet reported on the influence of Design Talks on participating teachers. This paper reports on a qualitative study focused on teacher reflections and perceptions of their experiences facilitating Design Talks in their classrooms. Specifically, we ask: *How do elementary teachers perceive the benefits of intentionally facilitated whole-class conversations during engineering design units?* Study participants were the six classroom teachers in our Design Talks community of practice.

## Background and Conceptual Framework

**Whole-class talk in science and math.** By using “Design Talks” as a catchphrase, we have hoped (1) to emphasize the importance of discussion in the learning of engineering, and (2) to explicitly align with seminal work on “science talks” (Gallas, 1995; Michaels & O’Connor, 2012) and “number talks” (Parrish, 2011) in elementary math and science education.

Science talk is a participation structure intentionally set up by teachers to allow both students and teachers to listen, understand, and explore different possible meanings of students’ ideas about natural phenomena, rather than to evaluate or correct those ideas (Michaels & O’Connor, 2012; Rosebery, Ogonowski, DiSchino, et al., 2010). It is also a discipline-specific outgrowth of the classroom discussion practices that comprise accountable talk, which help students listen and share ideas in ways that are accountable to the learning community, to disciplinary standards of reasoning, and to knowledge and evidence (Michaels, O’Connor, & Resnick, 2008). More recent work on whole-class science conversations has shed light on the pedagogical challenges and decision points that teachers face when facilitating them (Watkins & Manz, 2022, Chen & Qiao, 2020). For example, during a class discussion, teachers may need to decide when to make a proactive move that raises student uncertainty and sets students on a sensemaking trajectory (Chen & Techawitthayachinda, 2021; Ha, Chen, & Park, 2024). And when a student expresses uncertainty during a science talk, whether or not prompted by a teacher move, teachers need to decide how much space to make for that uncertainty, how to transform the uncertainty into a problem that the class collectively takes up, and how to engage classmates in evaluating different approaches to the problem (Watkins & Manz, 2022).

Number talks are short classroom conversations about mathematical computation problems that have been “purposefully crafted” for students to consider and discuss without needing to write out their work (Parrish, 2011). In developing teacher questions and facilitation moves for Design Talks, we drew upon this idea of a carefully framed launching prompt. In addition, we were also influenced by work in math education on “orchestrating” productive math discussions (Stein et al., 2008) and on setting sociomathematical norms in the classroom where students are invited and expected to share their nascent mathematical reasoning and ask questions about their peers’ mathematical ideas (e.g., Boaler, 2015; Chazan & Ball, 1999; McClain & Cobb, 2001).

One overall aim of the Design Talks project has been to explore whether and how principles for student-centered math and science discussions translate to engineering. Like math and science talks, Design Talks have a teacher-facilitated participation structure and a goal of developing practices of classroom discourse that can support students’ learning in a particular discipline, but in our case, that discipline is engineering.

Aligned with the sociocultural perspective underlying work on math and science classroom talk, we understand engineering design as a social practice (Bucciarelli, 1994; Dym et al., 2005; Jonassen et al., 2006) in which students are apprenticed into the disciplinary Discourse of engineering, or disciplinary ways of knowing, doing, talking, reading, and writing (Gee, 2014; Kittleson & Southerland, 2004). Our research on elementary engineering talk is rooted in prior work and theory highlighting the role of sensemaking, reflective decision-making, and perspective of care in the Discourse of engineering.

**Sensemaking.** Building on work in science education on sensemaking (Ford, 2012; Odden & Russ, 2018), we define sensemaking as a discursive process of constructing, critiquing, and revising an explanation to resolve a perceived gap or conflict in understanding. Engineering designers engage in *sensemaking* discourse to build understandings about the phenomena related to a design problem or potential design solution (Kelly & Cunningham, 2019; NRC, 2012). Sensemaking starts with a recognition that there is something puzzling that needs to be explained, such as an unusual observation, a conflict between ideas, or a gap in an existing explanation (Odden & Russ, 2018). In engineering design, this starting point can be an unexpected design performance or competing explanations about how and why a design works. Engineering students then recruit resources, both from their everyday experiences and more formal knowledge, to make new connections and build a coherent, explanatory account. Given the interdisciplinary nature of engineering, designers need to draw on diverse conceptual, material, and experiential resources to develop explanations (Dym et al., 2005). Mechanistic reasoning (Machamer, Darden, & Craver, 2000; Russ et al., 2008) also plays a central role in sensemaking about an engineering design's functionality.

**Reflective decision-making.** Also central to the work of engineering design is *decision-making* discourse, particularly decision-making that is informed by evidence from and reflection on stakeholders, criteria, previous design solutions, and test results (Crismond & Adams, 2012). The Framework for K-12 Science Education reminds us that "Engineers, too, make decisions based on evidence that a given design will work" (NRC, 2012, p. 62). Ethnographic studies of professional engineering practice show how iterative cycles of decision making are crucial for the design of working technologies (Atman et al., 2007; Aurigemma, Chandrasekharan, Nersessian, & Newstetter, 2013), and they emphasize that in engineering, decision making is a collaborative endeavor in which team members must negotiate constantly (Bucciarelli, 1994; Trevelyan, 2007). Research on elementary school engineering has shown that young students also engage in r*eflective decision-making* (Wendell, Wright, & Paugh, 2017). This discourse involves deciding what solutions to consider, how likely each potential solution is to solve the problem, which solution to invest time and resources in prototyping, how to test a prototype's performance, whether a prototype can be considered successful, and what improvements to make. Making these decisions is a different socio-cognitive task than sensemaking about how and why a problem needs to be solved, or how and why prototypes perform the way they do. Design Talks are intended to support both decision-making *and* sensemaking for engineering.

**Perspective of care.** Design Talks are also intended to equip students with the perspective that engineering is a caring endeavor, meaning that decision-making conversations also involve answering questions about who/what will be helped and who/what might be harmed by potential design solutions. This goal responds to calls to consider how to incorporate care and empathy in engineering education (McGowan & Bell, 2020; Gunckel & Tolbert, 2018). These perspectives challenge engineering as a "neutral" endeavor, instead highlighting the cultural, political, and historical dimensions of solving engineering design problems. Rather than focusing solely on the technical aspects of engineering, there is a need for educators to amplify a perspective of care, including considerations of power and inequality, potential for harm, and ecological stability (Gunckel & Tolbert, 2018). Students are often asked to envision the positive impacts of design solutions on society, but they are not often invited 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?"

Taken together, prior work and theory on sensemaking, reflective decision-making, and perspective of care led us to develop a Design Talks framework that includes five genres of classroom conversation. Initially informed by scholarly research characterizing engineering practices (e.g., Bucciarelli, 1994; Cunningham & Kelly, 2017), this set of five genres was settled upon by our teacher-researcher community after our first year of work together. At this point, we had implemented enough Design Talks to see that each focused on one of five particular goals for students' collective engineering design thinking. In distinguishing between different genres of engineering design conversations, we were building on a key takeaway from research on whole-class talk in math and science classrooms: pedagogical tools to support large-group conversation need to be strongly connected to the specific goals and purposes of that conversation (Michaels & O'Connor, 2012; Stein et al., 2008). As shown in Table 1, each Design Talk genre centers on a different framing question about a design problem or solutions and is facilitated by specific prompts that help students voice their ideas and make connections to others' ideas.

Here we summarize two sample Design Talks to give readers a sense of how they unfold in the classroom. In one Problem Scoping Design Talk, fifth grade students had just begun a design challenge focused on storm drain filters in their local community. They were considering the

Table 1. Five genres of Design Talks

| Genre | Are talks in which students… | Framing questions |
|---|---|---|
| **Problem Scoping Talks** | …negotiate the criteria and constraints for solving a design problem | ● Whose perspectives should we consider in solving this problem?<br>● What does our solution have to have to be successful?<br>● What constraints do we have in designing our solutions? |
| **Idea Generation Talks** | …elicit multiple ways of solving a problem | ● What ideas do you have for solving the design problem?<br>● How might different solution ideas work together? |
| **Design-in-Progress Talks** | …consolidate findings from building, testing, and iterating of artifacts | ● What problems did you encounter in building or testing your designs?<br>● (Select a particular prototype) What do you notice about this design? Why do you think it performs in this way?<br>● What changes should we make to our designs to make them more successful? |
| **Design Synthesis Talks** | …reason about multiple designs and synthesize common themes | ● What is something in your design or in somebody else's that you think worked very well?<br>● What do you notice across the different design solutions? What are different categories of solutions? |
| **Impact Talks** | …reflect on the different perspectives and relationships of those who may be impacted by a design | ● If we designed this solution, what might happen? Who might benefit and who might be harmed?<br>● Should we implement this design solution? Why or why not? |

problem of pollution entering storm drains. Previously, they had looked at their school playground's storm drains, viewed photos showing liquid and solid pollutants flowing into drains and exiting into a river, and observed solid debris physically clogging a drain and contributing to street flooding during a storm. Before they began to build and test prototype filters, their teacher engaged them as a whole class in a Problem Scoping Talk. To launch the conversation, she posed the questions, "So what would a successful solution do? What does your design have to do?" Her goal was for the students to generate a set of criteria for successful storm drain filters. Over the course of the talk, students identified stopping trash, blocking harmful liquids, and allowing water to enter the drain as three key functions that their filters needed to perform. They also explained that a sign of success would be to see trash all around their drain filters.

While Problem Scoping Talks typically occur near the beginning of an engineering design experience, another type of Design Talk – Design Synthesis – nearly always occurs at the end of an engineering design unit. For example, in a first-grade classroom, students had designed, constructed, and tested models of shade structures for their school's outdoor "buddy bench." Using a miniature bench and a flashlight standing in for the sun, the students tested their prototypes to see if they could provide shade during both morning and afternoon sunlight, while still allowing for visibility of the bench. Afterwards, with all the prototypes still visible on student desks, the teacher conducted a Design Synthesis Talk. This conversation enabled students to compare and contrast all of their designs and wonder about the reasons for similarities and differences. Students noticed that all successful shade structures had both a roof and side coverings, used rigid materials such as popsicle sticks for support beams, and included some small side holes for the bench user's view.

These two example talks were conducted in the classrooms of two teachers from the Design Talks community of practice. In this study, we investigated the perceptions of these teachers and four others, asking, *How do elementary teachers perceive the benefits of intentionally facilitated whole-class conversations during engineering design units?*

**Methods**

This qualitative study is part of a larger project in which university researchers partnered with K-6 teachers to develop Design Talks. We started in 2020 with two core teacher partners, meeting bi-weekly to discuss readings, plan engineering design units, and brainstorm structures for leading whole-class conversations within these units. Two additional teachers joined the team the following year; we continued to meet monthly to develop and refine different genres of Design Talks, collecting and discussing video of classroom enactments. We developed a website (engineeringdesigntalks.org) to disseminate our structures for whole-class conversations, including case studies and videos of exemplary Design Talks from partnering teachers' classrooms. In the final year we invited two additional teachers to review the website and implement a Design Talk in their classrooms; this approach allowed us to evaluate how the website serves as a dissemination tool and consider what other supports teachers might need to enact Design Talks. In Table 2 we summarize relevant characteristics of our six teacher partners and their schools.

Table 2. Key teacher and school characteristics

| Teacher | Grade Level | Genres of Design Talks Implemented | | | | | % Multilingual learners in school | % Low-income families in school |
|---|---|---|---|---|---|---|---|---|
| | | Problem Scoping | Idea Generation | Design-in-Progress | Design Synthesis | Impact | | |
| Molly | 1 | X | X | X | X | | 34% | 13% |
| Shannon | 3-4 | | X | X | | X | 34% | 13% |
| Rachel | 4 | | X | | | | 34% | 13% |
| Naina | 5 | X | X | X | X | | 73% | 59% |
| Rae | 6 | X | | X | | X | 73% | 59% |
| Vera | 6 | X | | | | X | 20% | 7% |

To examine teachers' perceptions of their experiences with Design Talks in their classroom, we asked them to respond to open-ended reflection questions (Table 3).

Table 3. Prompts for teacher reflection

| Prompt |
|---|
| 1. Think about a particular Design Talk you've led, what worked well, what was challenging? |
| 2. What do you think your students learned from engaging in Design Talks? Give examples… |
| 3. What's the same and different about Design Talks from other class activities and/or other classroom talks (in math or science or ELA)? |
| 4. If you were talking to another teacher and encouraging them to do Design Talks, what reasons would you give for trying them? |

We applied thematic analysis techniques (Braun & Clarke, 2006) of teacher responses, including initial coding followed by thematic mapping. We then compared our mapping to notes from teacher-researcher meetings over three years. The goal of this comparison step was to check for disconfirming evidence of the themes; we found none, confirming that teacher input during the meetings was in alignment with the four themes. We refined our preliminary themes by examining whether teachers were referring specifically to leading Design Talks in their classrooms or were referring to implementing engineering design projects more broadly. For instance, one potential theme centered on how Design Talks support students' agency and resiliency as in Naina's quote: "*I think like there was like a level of grit that was developed because it was like you kind of had to be like, oh, I tried this. It really didn't work and I got to try something else and I couldn't do it.*" We noticed that even if teachers referred directly to Design Talks, the theme was more about the advantages of the engineering design process rather than whole-class conversations embedded within them. With this refinement, we identified four central themes about teachers' perceptions of implementing Design Talks in their classroom.

## Findings

In this section we present four themes in teachers' reflections and perceptions of Design Talks after implementing them in their classrooms. Within each theme, we highlight the different ways that teachers talked about the affordances of DTs in their classroom as well as related challenges for facilitating DT with their students.

**Theme 1: Design Talks facilitate students' learning to listen, empathize, & communicate.** All six teachers discussed how DTs can support their students' discussion skills. For these elementary school teachers, learning to communicate constructively is a particularly important skill that they want their students to learn. Comments in this theme highlighted how DTs create a structured space for students to share their ideas with their peers, with the teacher facilitating to help them listen to and understand each other. For instance, Shannon, a 3rd- and 4th-grade teacher, was pleased by the ways that her students interacted in DTs:

> *"I was impressed with how well they built off each other's ideas! This group of friends needs support in how they speak to each other and this format helped them not only think about engineering but also built in the SEL skill of having a productive conversation. I was super impressed with how they did and the thinking they were capable of sharing."*

Shannon highlighted how these skills of learning to communicate effectively not only supports students' engineering, but also the socio-emotional skills of conversation. She reflected that her class at the time needed extra support in these skills and the structure of DTs offered that support. Naina, a fifth-grade teacher, shared similar comments:

> *"I thought it was once they became comfortable with like having the conversations, I thought it was really helpful for them to learn to collaborate with each. And I think they definitely unlocked like new levels of, like listening and collaborating during the Design Talks."*

Naina noticed how students progressed in becoming comfortable with whole-class discussions, which set the stage for their collaborations in small groups. By modeling how to listen and build on each other's ideas, students "unlocked" better skills for collaboration. Rae, a sixth-grade teacher, also shared stories of their students' progress:

> *"In design-in progress talks such as the wind turbine talk, students learned not only the engineering skills of considering multiple design factors in the process of iteration but also social emotional skills such as how to grow from their failures and how to truly listen to their peer's feedback. Due to their high motivation to improve their designs, students were more focused during discussions and really listening to their peers because they wanted the feedback which was evident from the way in which they add on to each others' ideas. In many of the years in which I taught 6th grade, the wind turbine project was the turning point in our class discussions serving as a model for how listening and commenting should be done in all discussions."*

Like Shannon, Rae highlighted how DTs address goals of learning engineering skills alongside socioemotional skills. Rae specified additional skills from DTs to include learning to grow from failures and respond to peers' feedback. In addition to providing structure to learn these skills, Rae highlighted another feature of DTs that supports students' learning to communicate: students are motivated to listen and share because they are motivated to improve their designs. They care about their own and each other's designs, which focuses them during these discussions. Like Naina, Rae commented on how engaging in DTs was pivotal in students' development in their classroom.

While all teachers commented on the benefits of DTs for students' communication, Vera also talked about the different role that a teacher plays in these conversations. Rather than leading students to a particular idea or perspective, teachers need to make space for students' differing ideas:

> *"As a teacher you model it to accept that there could be multiple outcomes and like, there's the values and beliefs that students bring into it. You can disagree with them. But you still have to account for them or allow them to be voiced. So those are kind of a, you know. Say, thinking of specific example of like the money. When somebody brings up the 'let's make it for profit.' And then you have students who have strong feelings about that. Do we? Do we monetize issues that we possibly created, you know? So that that comes up. But you also don't want to pass judgment on the students who say, 'No, absolutely, we should be rewarded in some way for doing this work.'"*

Vera's comments reflected on how to facilitate DTs to make space for diverse perspectives to be shared. She commented on how she had to model allowing differing ideas to be expressed, even if she disagreed with them. Science teachers, like Vera, are often tasked with supporting students to arrive at particular models or explanations—DTs mark a departure from that role. Vera's comments suggest that just as DTs offer structure for students to learn to listen to others, receive feedback, and process differing perspectives, DTs also offer opportunities for teachers to practice these skills as well.

**Theme 2: Design Talks provides opportunities for asset-based pedagogies.** Four of the six teachers discussed how DTs make space to showcase and value different students' assets for engineering learning. These comments often emerged as teachers compared their experiences leading other whole-class discussions. For instance, Rae, a sixth-grade teacher, talked about how DTs compare to other whole-class conversations in other subjects:

> "*Where you might analyze the perspective and impact of the design on different stakeholders in engineering, you can engage in a similar discussion in ELA to analyze different characters perspectives. The same could be said with brainstorming or synthesizing as those are skills that carry over into a wide variety of contexts. And in math we're often engaged in discussions with a similar feel as in-process talks to build on our knowledge to use increasingly complex skills in context. But with design talks, the end project or goal often feels more tangible than other discussions we may have in ELA, math, social studies and even science. Having a building project be the center of the discussion leads to more entry points for different types of students…"*

Rae's comments highlight similarities in learning goals between DTs and other classroom conversations in ELA or math. DTs support similar skills and practices, such as taking different people's perspectives, brainstorming ideas, synthesizing patterns, and using complex skills in context. Rae elaborated, however, that the unique aspect of DTs is combining these kinds of talks with a "tangible" design solution. This combination offers new "entry points" for "different types of students" to be able to contribute to these discussions. These different entry points to whole-class conversations enable more students to be able to participate and share their thinking, a key part of asset-based pedagogies.

Similarly, Vera, a sixth-grade science teacher, discussed how DTs offer more ways to build on different student strengths than a typical science discussion, which can focus narrowly on abstract concepts. By offering multiple ways of understanding a design problem or thinking about a proposed solution's impact, students can rely on each other's knowledge, but also bring their own understandings, experiences, and perspectives:

> "*It's not just about chemistry. There's other things that they can contribute. Yeah, because it allows them to - to bring the background knowledge into it, to share, like what they've seen before, what they think works, what doesn't work?*"

Vera's comments reflect prior research showing that engineering design projects can make space for students to draw on diverse assets for learning that are often not recognized in other subjects (Calabrese Barton, Schenkel, & Tan, 2021). With DTs, students not only draw on these assets, but are given space to publicly share their prior knowledge and experiences with their classmates. Other teachers' comments connect to this idea to suggest that DTs can broaden notions of smartness for students. For instance, Molly, a first-grade teacher, considered how students might be able to better recognize their own as well as their peers' strengths in DT:

> *"As I mentioned earlier there for some students, this way of being able to explain is the way they shine right? Like sometimes these ideas that they come up with is where they feel confident and excited and it's hands-on and it's relatable. And sometimes this is where they feel successful, right? Because during reading block they may not feel successful. They may really struggle in reading or writing, and for this to happen, for them to be able to participate in this kind of an experience. This might be an area where they're really successful, and it's such a confidence boost. I also think it's important for kids to see, you know, they pick up on things. They know, they understand that sometimes students are struggling, so being able for them to see like the value from their peers that they have really good ideas to share. You know, because they do, and it's just it's not necessarily always the way that we're able to show that to others"*

Molly highlights the ways that DT differs from other talks. For the students, the novelty of engineering, engaging in hands-on activities, and solving personally relevant problems can be a space for students to be successful when they might struggle in other activities like reading or writing. In addition to boosting their confidence, the public nature of whole-class conversations like DTs, as opposed to having students only work in small groups, means that these students will have opportunities to share their strengths with others. Therefore, DTs can provide space to disrupt academic hierarchies so that students can recognize the value of their peers' experiences and perspectives.

**Theme 3: Design Talks provide opportunities for students to take a perspective of care in engineering design.** Most teachers (all except one new DT teacher) discussed how DTs can shift students' sense of what concerns and whose concerns to prioritize in solving an engineering design problem. For instance, Rae had led several impact talks in their sixth-grade classroom, which they said helped students develop new ways of thinking about design problems:

> *"My students learned different skillsets and mindsets depending on the type of design talk we engaged in. For example, in the impact talks students learned how to evaluate the ethics of engineering choices by considering the position of power different stakeholders have in a project and how the outcome could affect them. This is not a skill often asked of students in the regular curriculum, particularly at the elementary level."*

Rae's comments point to the ways that DTs, particularly Impact Talks, can foreground ethics, power, and privilege in engineering design. For instance, in one talk, Rae challenged their students to consider the impacts of a large dam proposed for an area in the Brazilian rainforest. The students first watched a documentary video in which both proponents of the dam (mostly politicians and ranchers) and protestors (mostly members of a local Indigenous tribe) discussed their perspectives. Rae chose four arguments given by each side and asked students to consider them one at a time. Students individually ranked the argument as very strong, strong, weak, or very weak, then engaged in a whole-class discussion detailing their reasoning. In the resulting talk (Wendell et al., 2022), students considered the direct and indirect consequences of the dam, particularly for social, economic, and environmental injustice. They also make sense of the power that different communities had to influence decision-makers, integrating engineering design solutions with broader sociopolitical understandings.

Like Rae, many teachers talked about how Impact Talks can support students to take different perspectives of those who might be impacted by their designs. These comments cut across grade levels. For instance, Molly shared similar considerations about the benefits of DTs for her first graders:

> *"And so when we talk about things, well, who is who? Who is benefiting, who has benefited in the past and looking at it from that lens of, is this fair? Does fair always mean equal? What does that look like in our society? I think if we can kind of think those things through, it's another great way to extend. You know, I think sometimes we get stuck in, 'This is a science lesson or this is a social studies lesson,' and I think really getting them to see that like, no, the science impacts social studies, and social studies impact science, and math is needed, right? Like all of these pieces are connected. So I would encourage people to, you know, when they, when and if they do design talks, like incorporating that piece to it, that like there is a social justice lens to this, and you can't do it without that, like you have to think that through."*

Molly sees DTs as supporting her social justice goals in her first-grade classroom. Like the other teachers, she talked explicitly about how these talks can prompt students to consider who benefits from a design solution, but Molly added another consideration to prompt students to consider who has benefited historically from engineering solutions. Framed in an age-appropriate way for her first graders, she reflected on the deep questions that DTs can elicit around fairness, equality, and justice. Like Rae who incorporated DTs in their social studies curriculum, Molly positioned these talks as transdisciplinary, connecting multiple school subjects like science, social studies, and math that are often treated separately in the curriculum. For Molly, DTs are an authentic way to bring these subjects together to care about the world in which we live.

While most teachers commented on the benefits of DTs for empathy and perspective taking, Rae also talked about the challenges of facilitating these kinds of talks in her classroom:

> *I personally found it challenging to design the talk in such an ethical way that didn't put kids in the position of symbolically imposing their opinion onto far away people and situations. Thus, instead of asking them to form an opinion based on neutrally presented facts, I instead designed it so they had to respond to a quote from a documentary we watched and respond to how strong they believed each side's argument was, which worked really well. Time to build background knowledge is always a challenge in the classroom. While students had the knowledge that they had gained from their social studies learning… as well as the documentary about the specific issue, students didn't have a strong foundation about the history of land theft, genocide, and environmental degradation of Indigenous peoples and land. In this way they were somewhat limited in their responses and in a few examples oversimplified the task.*

Rae reflected on the Brazilian dam impact talk and the challenges of facilitating discussions about others' communities. Similar concerns have been raised about engineering more broadly, in which engineers are addressing or solving problems *for* others rather than *with* them (Costanza-Chock, 2020). Rather than positioning students as deciders of whether to build a dam in Brazil, Rae structured this Impact Talk so that students were engaging with the arguments made by different communities, including the Indigenous tribe opposing the dam and the agricultural industry in favor of the dam. By showing a documentary to develop students' understandings of the complexities of this situation, students could instead consider the strength of different arguments. While this approach mitigated some of their concerns about students making decisions based on "neutrally presented facts," Rae still grappled with the oversimplification of the design problem. They acknowledged that students had not had opportunities to develop understandings of the broader histories of oppression and genocide of Indigenous peoples, which limited how they could engage with the arguments about impact.

**Theme 4: Design Talks help students synthesize designs and their underlying concepts.**
Only two of the six teachers addressed the ways that DTs can support students' synthesis skills. Both Molly and Vera talked about the ways that DTs ground designs in key learning concepts and support students to make connections across designs. We included this theme because Molly talked at length about this benefit of DTs, perhaps because she led the most Synthesis Talks:

> *"This is this leads more into the design synthesis where we then grouped the items. So I guess it's a two in one, one design talk. But being able to kind of chat about the different ways that the models were similar, that worked really well. I think that they're able to,*

*you know. Based on some of the activities that we do in first grade, they're able to find things that are the same and things that are different. And I think that kind of having it was a really good conversation that we were able to have when we did that."*

Molly reflected on a Synthesis Talk she led with her first graders in which they grouped different design solutions into categories. Molly compared her students' engagement in that activity with the skills that are emphasized in first grade. Being able to compare and contrast is an important learning goal for her students, and DTs were a structured way to organize that learning for her students through conversation. Molly also reflected on how DTs reinforce conceptual learning goals as well:

> *"And I think just in general, you know, whatever topic we're working on, like whether it's the biomimicry or it's the sun and the buddy bench. I think being able to put their learning together right, like I was saying, you know, all of these pieces we learn about biomimicry. We learn about like plants and animals, but then being able to put all of that together to solve or to work on something. It's the same thing with the Sun, moon and stars with the buddy bench because they're learning all these pieces, but then having to put it together, and I think that that really pushes them to understand. And the concept that we're working on in like a deeper level."*

Molly's DTs were embedded in her science curriculum around core standards for her grade, including examining the different ways animals use their body parts and senses to survive and observing patterns in the movement of the sun, moon, and stars. She designed engineering lessons to reinforce these learning goals, for instance, asking students to design a shade for the playground buddy bench that would work throughout the day. Molly reflected that DTs help students connect these conceptual ideas with their designs. These connections are not automatic in integrated science and engineering lessons (Berland, Steingut, & Ko, 2014); DTs help to structure students to put these ideas together through teacher facilitation. For instance, Vera reflected on how she facilitated DTs to support this synthesis:

> *"It allows for higher level thinking, like comparing and merging ideas, making arguments for and against some idea or - and so I think it's also - so I think all of these - the challenging thing, and also a good thing. So you have to kind of create some kind of visual tracking of ideas for students who cannot keep track."*

While teaching older students than Molly, Vera's comments echoed how DTs address similar learning goals for her sixth graders—supporting them to synthesize across ideas and compare arguments. Amplifying the importance of teacher facilitation to support these goals, Vera advocated for a kind of "visual tracking" by the teacher, i.e., writing student contributions on the board or asking students to group their designs. Her comments highlight that DTs offer structure for student learning with teachers' skilled facilitation.

**Discussion and Conclusions**

Four themes emerged from our thematic analysis on teacher reflections about their experiences with Design Talks. These themes characterize how elementary teachers perceive the benefits of intentionally facilitated whole-class conversations during engineering design units. Teachers find that these conversations help them employ asset-based pedagogies while at the same time helping their students synthesize designs and their underlying concepts, take a perspective of care in engineering design, and learn to listen, empathize, and communicate.

One interesting aspect of these findings is that in their reflections on Design Talks, teachers centered what students *do* during the conversations. They did not focus on the design breakthroughs that occurred as a result of the conversations or on the assessment evidence the conversations generated. Instead, teachers who have been enacting Design Talks primarily value them for the discourse and design practices they foster among students in the moment. This finding is aligned with prior research on science talks in elementary classrooms, where the key goal was to help students express ideas about phenomena in ways that made sense to them as young people but were also accountable to a wider community (Michaels & O'Connor, 2012; Rosebery et al., 2010). In both science talks and Design Talks, the focus on sharing ideas among students, not just between student and teacher, supports students in participating collectively in disciplinary ways of knowing and doing, moving away from the little "d" discourse of 'academic' language toward what Gee (2014) would call big "D" Discourse.

The teachers' reflections highlighted how Design Talks put more ideas and perspectives on the table for students. For example, these ideas and perspectives came from peer feedback on designs-in-progress, from unique ways that other students explained their design ideas, and from disagreements between students about what design choices might be ethically acceptable. By putting students in contact with a broader diversity of perspectives on design problems and solutions, Design Talks could enrich sensemaking about how engineering designs work and decision-making about what to do next in a design process.

This perceived benefit of Design Talks is similar to an advantage of the approach to science talks described by Michaels and O'Connor (2012). Just as we explored distinct genres of Design Talks, Michaels and O'Connor defined different types of science talks, including one type called on explanation discussion. Here the goal is for students to make claims about why something happens and provide evidence to support the claims. An advantage to facilitating a whole-class discussion when trying to tie together claims and evidence is that with so many students involved, each individual student is introduced to multiple potential pieces of evidence for a claim they might want to defend. Teachers in the Design Talks project saw something similar happening across different types of whole-class engineering design discussions. They expanded the shared pool of ideas from which individual students could draw to refine their thinking about their own design problem or solution.

The findings of this study have implications for classroom practice and future work. They suggest that teachers see value in adding whole-class conversations to engineering design curriculum units. Any engineering design challenge can be deepened or extended by adding one or more Design Talk to the sequence of classroom activities for that challenge. Further research should explore how teachers' facilitation of Design Talks evolves over time and whether the perceived benefits shift along with the details of their facilitation approaches.

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**References**

Atman, C. J., Adams, R. S., Cardella, M. E., Turns, J., Mosborg, S., & Saleem, J. (2007). Engineering design processes: A comparison of students and expert practitioners. *Journal of Engineering Education*, 96(4), 359–379. https://doi.org/10.1002/j.2168-9830.2007. Tb00945.x

Aurigemma, J., Chandrasekharan, S., Nersessian, N. J., & Newstetter, W. (2013). Turning experiments into objects: The cognitive processes involved in the design of a lab-on-a-chip device. *Journal of Engineering Education*, *102*(1), 117-140.

Chazan, D., & Ball, D. (1999). Beyond being told not to tell. For the learning of mathematics, 19(2), 2-10.

Berland, L., Steingut, R., & Ko, P. (2014). High school student perceptions of the utility of the engineering design process: Creating opportunities to engage in engineering practices and apply math and science content. *Journal of Science Education and Technology*, *23*, 705-720.

Boaler, J. (2015). *Mathematical Mindsets*. San Francisco, CA: Jossey-Bass.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology*, *3*(2), 77-101.

Bucciarelli, L. (1994). *Designing engineers.* Cambridge, MA: MIT Press.

Calabrese Barton, A. M., Schenkel, K., & Tan, E. (2021). The ingenuity of everyday practice: A framework for justice-centered identity work in engineering in the middle grades. *Journal of Pre-College Engineering Education Research (J-PEER)*, *11*(1), 6.

Capobianco, B. M., DeLisi, J., & Radloff, J. (2018). Characterizing elementary teachers' enactment of high-leverage practices through engineering design-based science instruction. *Science Education*, 102(2), 342-376.

Carlone, H. B., Mercier, A. K., & Metzger, S. R. (2021). The production of epistemic culture and agency during a first-grade engineering design unit in an urban emergent school. *Journal of Pre-College Engineering Education Research (J-PEER)*, *11*(1), 10.

Chen, Y. C., & Qiao, X. (2020). Using students' epistemic uncertainty as a pedagogical resource to develop knowledge in argumentation. *International Journal of Science Education*, *42*(13), 2145-2180.

Chen, Y. C., & Techawitthayachinda, R. (2021). Developing deep learning in science classrooms: Tactics to manage epistemic uncertainty during whole-class discussion. *Journal of Research in Science Teaching*, *58*(8), 1083-1116.

Costanza-Chock, S. (2020). *Design justice: Community-led practices to build the worlds we need*. The MIT Press.

Crismond, D. P., & Adams, R. S. (2012). The informed design teaching and learning matrix. *Journal of Engineering Education*, 101(4), 738-797.

Cunningham, C. M., & Kelly, G. J. (2017). Epistemic practices of engineering for education. *Science Education*, *101*(3), 486-505.
Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J. (2005). Engineering design thinking, teaching, and learning. *Journal of Engineering Education*, *94*(1), 103-120. http://dx.doi.org/10.1002/j.2168-9830.2005.tb00832.x
Ford, M. J. (2012). A dialogic account of sense-making in scientific argumentation and reasoning. *Cognition and Instruction*, 30(3), 207-245.
Gallas, K. (1995). *Talking their way into science: Hearing children's questions and theories, responding with curricula*. New York, NY: Teachers College Press.
Gee, J. P. (2014). *An introduction to discourse analysis: Theory and method*. routledge.
Gunckel, K. L., & Tolbert, S. (2018). The imperative to move toward a dimension of care in engineering education. *Journal of Research in Science Teaching*, 55(7), 938-961.
Ha, H., Chen, Y. C., & Park, J. (2024). Teacher strategies to support student navigation of uncertainty: Considering the dynamic nature of scientific uncertainty throughout phases of sensemaking. *Science Education*, *108*(3), 890-928.
Jonassen, D., Strobel, J., & Lee, C. B. (2006). Everyday problem solving in engineering: Lessons for engineering educators. *Journal of Engineering Education*, 95(2), 139–151.
Kelly, G. J., & Cunningham, C. M. (2019). Epistemic tools in engineering design for K-12 education. *Science Education*.
Kittleson, J. M., & Southerland, S. A. (2004). The role of discourse in group knowledge construction: A case study of engineering students. *Journal of Research in Science Teaching*, *41*(3), 267-293.
Machamer, P., Darden, D., & Craver, C. F. (2000). Thinking about mechanisms. *Philosophy of Science*, 67, 1–25.
McClain, K., & Cobb, P. (2001). An analysis of development of sociomathematical norms in one first-grade classroom. *Journal for research in mathematics education*, 236-266
McGowan, V. C., & Bell, P. (2020). Engineering education as the development of critical sociotechnical literacy. *Science & Education*, *29*(4), 981-1005.
Michaels, S., O'Connor, C., & Resnick, L. B. (2008). Deliberative discourse idealized and realized: Accountable talk in the classroom and in civic life. *Studies in philosophy and education*, *27*, 283-297.
Michaels, S., & O'Connor, C. (2012). Talk science primer. *Cambridge, MA: TERC. Available online at http://inquiryproject.terc.edu/shared/pd/TalkScience_Primer. pdf*.
National Research Council. (2012). *A framework for K-12 science education: Practices, crosscut- ting concepts, and core ideas.* Washington, DC: The National Academies Press. https://doi. org/10.17226/13165
Odden, T. O. B., & Russ, R. S. (2018). Sensemaking epistemic game: A model of student sensemaking processes in introductory physics. *Physical Review Physics Education Research*, 14(2), 020122
Parrish, S. D. (2011). Number talks build numerical reasoning. *Teaching Children Mathematics*, *18*(3), 198-206.
Rosebery, A. S., Ogonowski, M., DiSchino, M., & Warren, B. (2010). "The Coat Traps All Your Body Heat": Heterogeneity as fundamental to learning. T*he Journal of the Learning Sciences*, 19(3), 322–357.

Russ, R. S., Scherr, R. E., Hammer, D., & Mikeska, J. (2008). Recognizing mechanistic reasoning in student scientific inquiry: A framework for discourse analysis developed from philosophy of science. *Science Education*, 92(3), 499-525.

Stein, M. K., Engle, R. A., Smith, M. S., & Hughes, E. K. (2008). *Orchestrating productive mathematical discussions: Five practices for helping teachers move beyond show and tell.* https://doi.org/10.1080/10986060802229675

Trevelyan, J. P. (2007). Technical coordination in engineering practice. *Journal of Engineering Education*, 96(3), 191–204. https://doi.org/10.1002/j.2168-9830.2007.tb00929.x

Watkins, J., & Manz, E. (2022). Characterizing pedagogical decision points in sense-making conversations motivated by scientific uncertainty. *Science Education*, *106*(6), 1408-1441.

Wendell, K., Watkins, J., Andrews, C., DeLucca, N., Pangan, T., Woodcock, R., Gor, V., Malinowski, M., Sood, N. (2024). Design Talks: Whole-class conversations during engineering design units. *Science and Children. 61*(1). https://doi.org/10.1080/00368148.2023.2292391

Wendell, K., Watkins, J., Andrews, C., Malinowski, M. (2023). The Role of Whole-Class Conversations in Supporting Early Elementary Students' Engineering Design Sense-Making. *Proceedings of the Annual Meeting of the International Society of the Learning Sciences (ISLS)*.

Wendell, K., Watkins, J., Andrews, C., De Lucca, N., Pangan, T. J., Woodcock, R. (2022). "Should we build this?": Student reasoning in intentionally facilitated socio-technical design talks. *ASEE Annual Conference proceedings*.

Wendell, K. B., Wright, C. G., & Paugh, P. (2017). Reflective decision-making in elementary students' engineering design. *Journal of Engineering Education*, *106*(3), 356-397.