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RESEARCH ARTICLE

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Characterizing engineering outreach educators' talk moves: An exploratory framework

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Abstract

Background: Despite the prevalence and potential of K–12 engineering outreach programs, the moment-to-moment dynamics of outreach educators' facilitation of engineering learning experiences are understudied. There is a need to identify outreach educators' teaching moves and to explore the implications of these moves.

Purpose/Hypothesis: We offer a preliminary framework for characterizing engineering outreach educators' teaching moves in relation to principles of ambitious instruction. This study describes outreach educators' teaching moves and identifies learning opportunities afforded by these moves.

Design/Method: Through discourse analysis of video recordings of a university-led engineering outreach program, we identified teaching moves of novice engineering outreach educators in interaction with elementary student design teams. We considered 18 outreach educators' teaching moves through a lens of ambitious instruction.

Results: In small group interactions, outreach educators used ambitious, conservative, and inclusive teaching moves. These novice educators utilized talk moves that centered students' ideas and agency. Ambitious moves included two novel teaching moves: design check-ins and revoicing tangible manifestations of students' ideas. Ambitious moves offered students opportunities to engage in engineering design. Conservative moves provided opportunities for students to make technical and affective progress, and to experience engineering norms.

Conclusions: Our work is formative in describing engineering outreach educators' teaching moves and points to outreach educators' capability in using ambitious moves. Ambitious engineering instruction may be a useful framework for designing engineering outreach to support students' participation and progress in engineering design. Additionally, conservative teaching moves, typically considered constraining, may support productive student affect and engagement in engineering design.

KEYWORDS
ambitious instruction, discourse analysis, elementary school, engineering outreach, pedagogy

1 | INTRODUCTION

Engineering outreach programs have the potential to significantly influence youth: approximately 600,000 K–12 students participate in university-led engineering education each year in the United States (Iversen, 2016). Despite the prevalence of engineering outreach education, the moment-to-moment dynamics of outreach educators' facilitation of engineering learning experiences are understudied. Engineering outreach educators' teaching moves warrant study for two primary reasons. First, outreach educators and schoolteachers operate within different parameters and are afforded varied opportunities to select or design curriculum and set goals related to student outcomes. Second, by design, engineering outreach programs foreground the discipline of engineering. In other contexts, engineering instruction may be integrated with additional disciplines, particularly science (Advancing Excellence in P–12 Engineering Education & American Society for Engineering Education [AE3 & ASEE], 2020). Studying engineering-specific instruction provides opportunities to identify teaching moves that specifically support the goals of engineering education. This study expands our understanding of engineering educators' teaching moves by exploring the in-the-moment discourse of educators facilitating a university-led engineering outreach program.

Our goal is to describe the kinds of discursive teaching moves outreach educators (OEs) enact when interacting with elementary student design teams, particularly those that are likely to support students to participate in and make progress in engineering. As ambitious teaching practices have been found to correspond with productive student participation and outcomes, (e.g., Grinath & Southerland, 2019; Smith et al., 2001; Windschitl et al., 2012), we use a lens of ambitious instruction to explore and describe the teaching moves of engineering outreach educators and consider the implications for supporting students to participate in engineering. We ask two research questions:

1. What types of ambitious, conservative, and inclusive discourse moves emerge in engineering outreach educators' interactions with student design teams?
2. What opportunities do ambitious and conservative teaching moves afford within engineering outreach classrooms?

2 | HISTORICAL AND CONCEPTUAL FRAMEWORK

2.1 | Engineering participation as learning

We follow a situative theory of learning, viewing learning to be a result of social and cognitive participation in activities, rather than as acquisition of content knowledge (Greeno & Engeström, 2014; Sfard, 1998). Specifically, we consider participation in activities that engage students in authentic engineering practices to be evidence of engineering learning (AE3 & ASEE, 2020; Engle & Conant, 2002; Herrenkohl & Guerra, 1998; Lave & Wenger, 1991). Elementary students who engage in engineering design challenges have been seen to demonstrate productive beginnings of professional practices such as problem-scoping and reflective decision-making (Watkins et al., 2014; Wendell et al., 2017). To learn engineering, youth must have opportunities to participate in developmentally appropriate, authentic engineering activities (AE3 & ASEE, 2020).

2.2 | Engineering teaching as providing opportunities for participation

As we take participation in engineering practices and activities to be evidence of learning, we see productive engineering teaching as actions that provide equitable opportunities for students to participate in engineering. Such actions broadly include both in-the-moment discourse and preplanned design of the learning environment (Kelly & Green, 2019). Here, we focus on outreach educators' fine-grained verbal discourse that provides opportunities or makes space for students to engage in engineering. We situate this study within bodies of research focused on developing meaningful and equitable participation for all learners. Primarily, we draw on research that indicates certain educator talk moves expand opportunities for students to share their ideas (Haverly et al., 2020), while other, more didactic talk moves constrain or shut down productive interactions (Michaels & O'Connor, 2015; Zhai & Dillon, 2014). Integrating this research with studies of engineering norms that emphasize reflective, collaborative decision-making (Crismond & Adams, 2012; Tonso, 2006; Wendell et al., 2017), we see educator talk moves as tools that position learners as iterative co-developers of knowledge (Calabrese Barton & Tan, 2010; Gutiérrez & Rogoff, 2003). This aligns with claims that supporting students' agentive, collaborative engineering design necessitates teaching moves grounded in eliciting, noticing, and responding to students' unique design ideas and artifacts (Watkins et al., 2020; Watkins & Portsmore, 2021).

2.3 | Engineering outreach as a context for learning and teaching engineering

Youth learn engineering in a variety of complementary in-school and out-of-school contexts, including university-led engineering outreach. Broadly, engineering outreach includes facilitated engineering design activities, presentations about engineering careers, and demonstrations of engineering activities or technologies. Engineering outreach may occur as public festivals, afterschool clubs, or invited in-school activities. This study is situated in a classroom-based engineering outreach program, and henceforth, when we refer to engineering outreach, we mean in-school activities that engage youth in engineering design challenges facilitated by invited guest educators, rather than schoolteachers.

As engineering education has gained prevalence in elementary schools, often it has been nested within science education or used to support science learning (Next Generation Science Standards Lead States [NGSS], 2013; Wendell & Rogers, 2013). Researchers have begun to characterize engineering teaching moves within science classrooms (Capobianco et al., 2018), offering insight into ways educators teach engineering embedded in science education. Engineering-centered teaching is likely to be a different endeavor than teaching engineering to support science learning, as the goals for and practices of engineering learning are different from those of science learning (AE3 & ASEE, 2020; Cunningham & Carlsen, 2014). Elementary engineering outreach programs offer a noteworthy opportunity to study educators' pedagogical moves in a context that specifically foregrounds engineering.

2.4 | School-based outreach as a pedagogical context

Taking a sociocultural and situated perspective on teaching, we recognize that educators' pedagogies are influenced by the contexts in which they teach and their own histories as teachers and learners (De Lucca et al., 2021; Gutiérrez & Vossoughi, 2010; Lortie, 1975; Putnam & Borko, 2000). Studies of outreach, school, museum, and workplace education suggest particular pedagogies may correspond with attributes of formality and informality in a given setting (Ash et al., 2012; Bevan, 2016; Colley et al., 2003; Dillon, 2016; Gartland, 2021; National Research Council [NRC], 2009, 2015). We recognize that within and across in-school outreach contexts there may be formal and informal attributes and moments of teaching and learning (Bevan, 2016; Colley et al., 2003). Recent shifts in the conceptualization of learning environments suggest that we should think of outreach educators as drawing on both formal and informal pedagogies within learning experiences (Bevan, 2016; Bevan & Michalchik, 2013; Gartland, 2021; Gutiérrez & Vossoughi, 2010; Vossoughi et al., 2021).

2.5 | Pedagogy of outreach educators

Although outreach educators may teach within schools, they often perform a different role than do schoolteachers and they may hold different pedagogical goals and employ alternative teaching moves than do other educators (Bledsoe et al., 2004; Gartland, 2015). Although studies suggest OEs are capable educators (e.g., Gamse et al., 2010), little is known about the in situ pedagogies and teaching moves of effective OEs (Gartland, 2021). Typically, engineering outreach programs are designed to invite and enculturate students into engineering via two functions: modeling enthusiasm for engineering study and careers and facilitating participation in engineering practices (Bers & Portsmore, 2005; Bledsoe et al., 2004; Cunningham & Lachapelle, 2016; Gartland, 2015; Higgins & Hertel, 2013; Portsmore et al., 2003). University-led outreach is often facilitated by undergraduate or graduate engineering students who are well-positioned to perform both these functions. Concurrently, these OEs are novice educators who are developing their own pedagogical knowledge and practices (Ball & Cohen, 1999; Halim et al., 2021; Shulman, 1986).

In terms of pedagogical skills, OEs may be akin to novice educators, as many OEs are new to teaching; additionally, while OEs may have participated in discipline-specific training, they have not participated in the pedagogical training typical of traditional preservice teacher preparation programs (Halim et al., 2021; Thiessen, 2000). The field's current understanding of novice educators' pedagogical skills is mixed. Novice educators may initially emulate the typically didactic pedagogical methods they experienced as students (Lortie, 1975), center their own actions, rather than students' activity (Kagan, 1992), and focus on addressing operational challenges such as classroom management (Veenman, 1984). However, more recent evidence suggests that novice educators are capable of actions that support more student-centered pedagogical approaches, such as attending to and adjusting instruction to respond to student thinking, particularly when provided opportunities to learn and rehearse such pedagogies (Levin et al., 2009; Stroupe et al., 2021).

2.6 | Ambitious instruction

To understand the scope of OEs' instructional moves, we consider OEs' talk through a lens of ambitious instruction. Ambitious instruction originated as a call to engage all students in challenging, meaningful academic work (Cohen & Spillane, 1992; Fuhrman & Massell, 1992; Lampert et al., 2010; Newmann, 1996; Sebring et al., 2006). In ambitious instruction, educators attend to students' ideas and adapt pedagogical moves to support students to (1) engage in authentic disciplinary activity and (2) sense-make with their own and peers' ideas (Kazemi et al., 2009; Singer-Gabella et al., 2016; Windschitl et al., 2012).

2.6.1 | Approaching ambitious engineering instruction through ambitious science teaching

Ambitious instruction has been amply described in science, mathematics, and language education (e.g., Lampert et al., 2011; Singer-Gabella et al., 2016; Stein et al., 2008; Windschitl et al., 2012, 2018), yet it has just begun to be characterized in engineering. Research describes the pedagogical moves of K–12 integrated science and engineering teachers (Capobianco et al., 2018), but little is known about the pedagogical moves of engineering-specific teachers, including OEs. Since there is not an extant framework for ambitious engineering instruction, we look to ambitious science teaching (Windschitl et al., 2012) for inspiration.

While we acknowledge similarities between science and engineering teaching goals and practices, we also recognize discipline-specific differences in student engagement and learning. In both science and engineering, we expect ambitious instruction to support students to sense-make: to express and refine their ideas about the material world, and to "figure something out" (Odden & Russ, 2019). Ambitious science teaching includes three teacher discourse practices: eliciting students' ideas to adapt instruction; helping students make sense of material activity; and pressing students for evidence-based explanations (Windschitl et al., 2012). In science teaching, these discourse practices support students to reason about natural phenomena; in an engineering outreach context, we expect corresponding discourse practices that support students to reason about design problems and solutions. Additionally, ambitious science teaching engages students in sensemaking to develop a whole-class consensus explanation or model of a natural phenomenon. In contrast, we conjecture, ambitious engineering outreach teaching engages students in sense-making about a set of possible solutions to one or more design problems such that one student team in a classroom may be reasoning about a different design problem or solution than another student team.

Educators' talk can scaffold students' engagement in collaborative sensemaking; ambitious teacher talk creates space for students to make their ideas public, listen to peers' ideas, think with peers, and refine their thinking (Michaels et al., 2008; Michaels & O'Connor, 2012; Schwarz et al., 2021; Windschitl et al., 2012). In engineering, we would expect educators to offer opportunities for students to generate and refine their own ideas through engagement in engineering design practices including problem-scoping, envisioning, building, testing, iterating, and reflective decision-making (Crismond & Adams, 2012; NRC, 2012; NGSS, 2013; Wendell et al., 2017). Accordingly, we forefront outreach educators' talk moves, highlighting the discursive bids OEs make that afford students opportunities to build on their own ideas to make progress in engineering. Through this lens of ambitious instruction, we explore the teaching moves of OEs in an elementary engineering context. To establish a baseline understanding of existing talk moves, we focus on two research questions:

1. What types of ambitious, conservative, and inclusive discourse moves emerge in engineering outreach educators' interactions with student design teams?
2. What opportunities do ambitious and conservative teaching moves afford within engineering outreach classrooms?

3 | METHODS

3.1 | Epistemology and researcher positionality

We are current and former outreach educators, K–12 schoolteachers, university instructors, teacher professional development providers, and engineering and science education researchers. Three of us have worked in engineering and science education outreach for 15 or more years as outreach educators and outreach program directors. The authors of this study engaged in varied roles, including serving as an OE, providing OE training, or collecting and/or analyzing data.

We started from the premise that educators make complex decisions in real time, situated in rich contexts. Accordingly, we followed a qualitative descriptive research paradigm. We endeavored to describe how OEs interacted with youth, yet existing frameworks were insufficient for considering the intersection of formal and informal learning, teacher talk in interaction with small groups, and K–12 engineering learning. Thus, we drew on ambitious science teaching as a starting point and selected a naturalistic inquiry approach, observing and describing classroom interactions (Lincoln & Guba, 1985). Additionally, we took a sociolinguistic perspective, attending to discourse as language-in-use and as negotiated meaning within a shared sociocultural context (Gee, 2014).

3.2 | Study context

This study took place within a university-led engineering education outreach program in the northeastern United States. Pairs of university students, the outreach educators, facilitated engineering design challenges in elementary school classrooms for 1 h each week throughout the school year, for a total of 12–18 design sessions. The OEs were recruited to work in the program through recruitment talks in engineering classes, on-campus posters, and campus job fairs. OEs were paid hourly wages consistent with other on-campus jobs. Employment as an OE was not contingent on research participation.

The program took place during the school day and included all students in a classroom. Participating students and classrooms were representative of their larger school population; they were not selected based on students' interest, behavior, nor academic performance. Each classroom participated in a varied set of design challenges jointly selected by OEs and classroom teachers. OEs presented a problem and student teams envisioned, constructed, and tested an object intended to solve the problem. A typical session began with OE-led whole group instruction, then shifted to students working in small groups of two or three students to plan, build, test, and iterate on their design solutions using craft materials, simple electronics, or LEGO bricks and robotics. Sample activities included creating model houses that could withstand simulated hurricanes and earthquakes or designing music boxes using LEGO robotics materials.

3.3 | Participants

The study protocol was reviewed and approved by a university Institutional Review Board. We obtained informed consent from participating OEs and schoolteachers, we obtained assent from participating students, and we obtained permission from parents or guardians of participating students. Outreach educators, schoolteachers, and students who opted not to participate in the research continued to participate in the outreach program, but we did not collect data from these individuals.

This study involved 18 engineering OEs' interactions with teams of fourth- and fifth-grade students from 10 classrooms across four schools. We report OEs' gender, major study area, and teaching experience in Appendix A, Table A1. Although we wish to be transparent about OEs' racial identities, we do not have sufficient information nor consent to do so. All OEs in the program were invited to participate in the research; in the three primary years covered by this study, there were, on average, 58 OEs each year and 92% participation in the larger study.

The OEs had participated in the outreach program for between one and six semesters and in 10–15 h of training annually. Training meetings oriented OEs to the goals of the outreach program, specifically around engaging students in open-ended engineering design activities that supported engineering norms of collaboration, iteration, solution diversity, reflective decision-making, and sensemaking (AE3 & ASEE, 2020; Roth, 1995, 1996; Wendell et al., 2017). Training also supported OEs to build rapport with students, develop classroom management skills, and gain familiarity with educational tools (e.g., LEGO robotics and Squishy Circuits). Although the outreach program intended to support students to sense-make in engineering, OE training did not include information about ambitious instruction or discourse moves.

3.4 | Data collection and reduction

We made multiple video- and audio-recordings of each engineering outreach design session to acquire optimal data in an active classroom. Recording included voice recorders on OEs, whole-class video, focused video of student groups, and supplemental voice recording of student groups. OEs utilized little whole-class discussion or interaction, quickly setting up engineering challenges and then supporting students by circulating through the classroom and spending time with individual groups. Hence, we focused on OEs' interactions with small groups of students. We analyzed these interactions with 12 focal groups; each focal group included one team of two or three students in a single design session. We selectively sampled 12 student groups across participating classrooms because they represented clear and complete recordings of a variety of engineering activities and classrooms; thus, the 18 OEs and the 24 student participants were selected by convenience. Table B1, Appendix B describes the OEs, students, and activities in the data set. While we analyzed a representative sample of design sessions and groups in this study, our selection was constrained by the limitations of video recording in classrooms, including students walking out of range of the recording devices and the inability to distinguish an individual's talk amidst the cacophony of exuberant collaboration.

For each focal group, we compiled all video and audio recordings that included the selected student team interacting with the OEs during a single design session. We included recordings of students working in small groups and excluded segments of recordings when OEs addressed the entire class, such as when OEs introduced the design challenge. Each compiled set of recordings included video and audio from up to five cameras and five voice recorders. Reviewing recordings made in multiple locations within the classroom allowed us to follow each focal group as the students moved around the room. We used the data from these complementary recordings to compile a single transcript for each focal group of students. Compiled, nonduplicative recordings of individual focal groups ranged from 19 to 51 min in total length, averaging 35 min.

3.5 | Data analysis

3.5.1 | Analytic framework

Our goals in this paper are to explore what kinds of teaching moves novice OEs naturally use and how these moves could be productive in engineering outreach education. We examine the fine-grained teaching moves that comprise high-level discourse practices and provide space for students to share their ideas, offer opportunities for students to make sense of material activity, and press students to reason with evidence. To that end, we build upon Grinath and Southerland's (2019) taxonomy of talk moves and look for ambitious, conservative, and inclusive talk moves. Ambitious talk moves elicit and encourage student reasoning, conservative moves elicit an anticipated answer or deliver information, and inclusive moves give multiple students a voice in the discussion of the disciplinary activity. There are discipline-specific differences in the substance about which students are reasoning; in science, we expect teachers to scaffold explaining phenomena, while in engineering we would expect OEs to scaffold reasoning about design solutions. Table 1 shows the alignment and divergence we anticipate when comparing science and engineering educators' discourse moves.

TABLE 1 Alignment and divergence in science and engineering educators' discourse moves.

	Science educator discourse moves (Grinath & Southerland, 2019; Windschitl et al., 2018)	**Engineering outreach educator discourse moves**
Ambitious	Elicit student explanations of a phenomenon	Elicit or encourage student reasoning about a design problem or solution
Conservative	Elicit an anticipated answer or deliver information	Elicit an anticipated answer or deliver information
Inclusive	Give multiple students a voice in the discussion of the phenomenon	Give multiple students a voice in the discussion of the design product or process

Note: In figures and tables, ambitious, conservative, and inclusive talk moves are color-coded yellow, blue, and vermillion, respectively, to aid recognition of talk move categories throughout the manuscript.

3.5.2 | Analytic process

We transcribed the recordings of the focal groups, then identified and analyzed OE talk turns as embedded units of analysis within each of the 12 focal groups, excluding turns of talk directed to other student groups or to the entire class. We conducted four cycles of qualitative, iterative, adjudicated coding (Miles et al., 2013) (Table C1, Appendix C). We first watched the videos, and then we coded the transcripts. Throughout our analysis, we referred to video recordings to resolve discrepancies and understand nuances of the interactions. Initially, we collaboratively discussed and coded OE talk turns from two focal groups using an a priori coding system derived from Grinath and Southerland (2019). In the two subsequent cycles, we refined the codebook and coded eight additional focal groups. In the final cycle, we coded two new focal groups and reviewed six focal groups from earlier coding cycles to ensure consistency. In the second, third, and final coding cycles, the first author segmented and independently coded each transcript and the second author independently coded the segmented transcripts. In these cycles, after we completed the independent coding, we calculated intercoder agreement for each transcript by dividing the number of times the coders agreed by the total number of talk turns coded in that transcript. In the third and fourth cycles, intercoder agreement for each transcript ranged from 69% to 90% and overall intercoder agreement across all transcripts was 79%. Finally, the first, second, and third authors adjudicated any discrepancies through discussion to achieve consensus.

While we maintained Grinath and Southerland's (2019) three categories of teaching moves—ambitious, conservative, and inclusive moves—we modified the original coding scheme to emphasize engineering sensemaking and engineering outreach norms. When we identified talk moves that did not fit the codebook, we flagged them for further discussion, ultimately adding and refining codes. We added an ambitious move (design check-in) and distinguished between revoicing and repeating. We took "revoicing" to be rephrasing of a student's idea and "repeating" to be word-for-word echoing of a student's speech. We categorized repeating as inclusive because it marked a student's contribution and thus offered them a voice in the discussion. We saw revoicing as ambitious because, in addition to marking a

TABLE 2 Codebook overview.

Talk move	Description
Ambitious: Elicit and encourage student reasoning	
Design check-in[a]	An open-ended question or statement that does not specifically reference a group's design, yet offers students the opportunity to talk about or show their design ideas
Probing question and follow-up probe[b]	An open-ended question that focuses on a student's design ideas or thinking (and serves to surface student ideas about their design)
Press for explanation[b]	Press for student reasoning about a mechanism or a design choice
Revoice or reflect[a]	Paraphrase or highlight a selection of a student's design-related comment, or voice what the educator notices the student is doing with their design
Conservative: Elicit an anticipated answer or deliver information	
Display question[b]	Request for simple facts, procedures, or identification of students' status in the activity; prompts for a report or a single correct answer
Evaluate correctness[b]	Categorize student's response, product, or process as normative, useful, or productive (or not)
Minilecture or suggestion[b]	Respond to student contribution by delivering content in the form of a design-related suggestion, content about the activity, or disciplinary norms
Process management[a]	Remind students about the activity instructions, materials, or time
Inclusive: Give multiple students a voice in the disciplinary discussion	
Distribute participation[b]	Provide an opportunity for additional students to contribute, respond, or build
Acknowledge contribution	Indicate student's contribution is valuable without indicating correctness or indicate listening and encouragement
Repeat[b]	Repeat student's contribution to ask for clarification or to acknowledge a student's idea
Other	
Other[a]	Filler words and unspecific feedback

[a]A talk move type is new to this framework.
[b]A talk move type has been modified from the Grinath and Southerland (2019) framework.

student's contribution, it selectively focused attention on the student's thinking and offered them an opportunity to respond to an OE's interpretation of their idea. In this way, we recognize that while ambitious moves are inherently inclusive, the converse is not necessarily true. Table 2 shows our modifications, while Appendix D (Table D1) shows our full codebook.

We marked each talk turn with a single code. If a talk turn could be interpreted to contain multiple codes, we selected the predominant code, with the exception of double-coding inclusive moves if they occurred in the same talk turn as an ambitious or conservative move, as inclusive moves represented only 12 of 720 talk turns. In total, OEs utilized ambitious, conservative, or inclusive talk moves in 533 of 720 (74%) turns of talk. The remaining 26% of educators' talk turns were ambiguous utterances (e.g., "OK"). We acknowledge the ambiguous utterances as contact points with students, yet we excluded these talk turns from further analysis because we could not ascribe an intent to them.

After we identified talk move types, we performed a thematic analysis focused on the opportunities afforded by talk move types. We reviewed all of the coded transcripts and considered the function of each talk move type. We asked ourselves what kinds of engineering learning opportunities were afforded by individual talk moves. Next, we discussed our interpretations across each type and category of talk move. For the broad categories of talk moves (ambitious, conservative, and inclusive), we identified possible themes centered on ways that these moves could support engineering learning. Finally, we identified exemplar vignettes and intensity cases—cases that represented a phenomenon richly, but not extremely (Carlone et al., 2021; Miles & Huberman, 1994; Patton, 2002; Russ, 2018). We present these vignettes and intensity cases as evidence of the ways certain talk moves emerged as potentially productive or unique within engineering outreach.

4 | FINDINGS

In our characterization of OEs' talk moves, we first describe the prevalence of ambitious, conservative, and inclusive talk moves and their distribution within the above categories. We then highlight novel talk moves that may be specific to engineering outreach. We provide evidence that ambitious and conservative moves may serve different productive roles in engineering outreach.

4.1 | Characterization of outreach educators' talk in engineering

4.1.1 | Distribution of talk moves

To understand the range of talk patterns we observed, we calculated the distribution of ambitious, conservative, and inclusive moves for each of the 12 focal groups. Figure 1 shows this distribution.

The distribution of talk moves across categories was similar across focal groups. In 11 of the 12 focal groups, conservative moves dominated OEs' talk and ambitious moves were the next most prevalent. Inclusive moves were rare across all groups. There were differences among focal groups; ambitious moves ranged from 6% to 50% of all focal talk moves, conservative moves ranged from 42% to 94%, and inclusive moves ranged from 0% to 12%.

We next explored which types of moves were especially prevalent or rare. Figure 2 depicts the prevalence of each move type within the categories of ambitious, conservative, and inclusive moves (aggregated across all focal groups).

Prevalence of ambitious moves

Ambitious teaching was not a focus of the professional development for the OEs in the program; thus, we were surprised to observe that 20% of OEs' talk moves were ambitious. The most common ambitious move (8% of talk moves) was a probing question, in which educators elicited students' design ideas and reasoning. At times, but less frequently (2%), OEs followed a probing question with a press for explanation of students' reasoning about the design problem or solution. Design check-ins and revoicing made up 4% and 6% of talk moves, respectively. Although ambitious moves were not the most common OE talk moves, it is notable that every OE organically used ambitious moves.

Prevalence of conservative moves

Not only were conservative moves the most common category of talk move, every type of conservative move occurred more frequently than any type of ambitious or inclusive move. OEs engaged in process management more than any

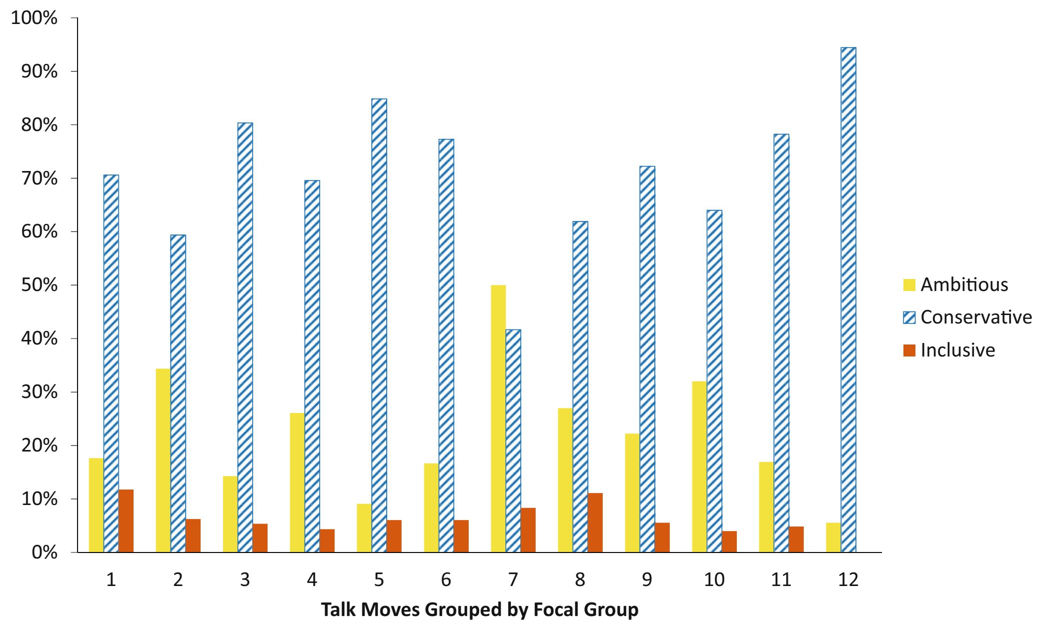

FIGURE 1 Distribution of ambitious, conservative, and inclusive moves by focal group.

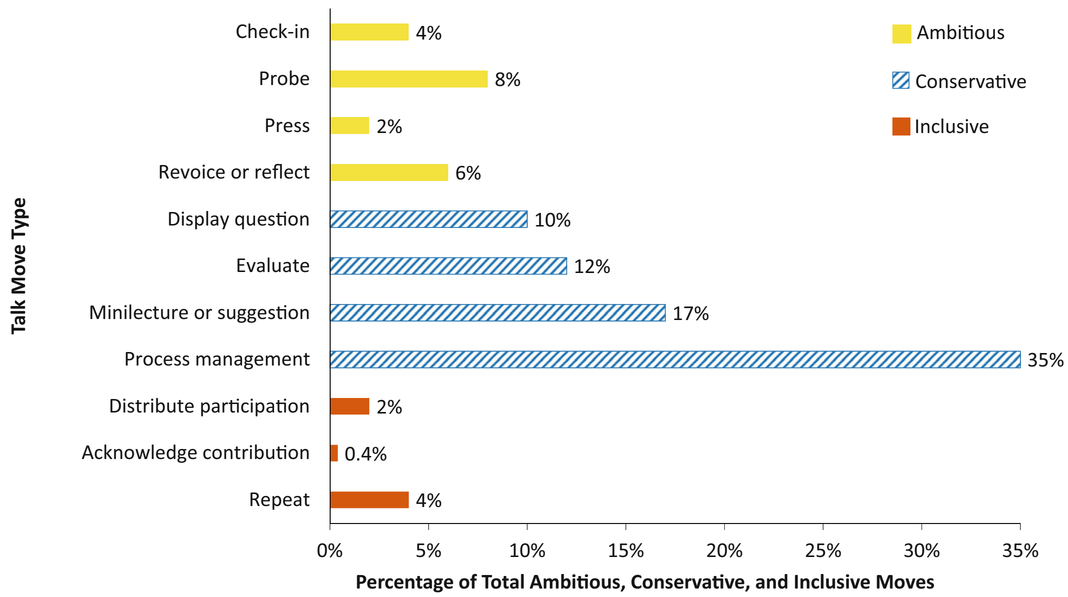

FIGURE 2 Distribution of talk move types within the ambitious, conservative, and inclusive categories.

other type of talk move; one third of OEs' talk with students focused on reminders about or offers of assistance with tools, materials, or time. In this outreach context, OEs facilitated design experiences during which students interacted with open-ended challenges, manipulated a variety of materials, and coordinated actions with peers. It is reasonable to expect that OEs might spend considerable time helping students manage the process, tools, or materials. Given the time constraints of the program, it is also possible that OEs used process management moves to ensure that students completed a design challenge or made enough progress to feel successful.

Prevalence of inclusive moves

Inclusive moves were infrequent, representing only 12 of 720 talk turns. Repeat and distribute participation were most prevalent and acknowledge contribution was rare. The scarcity of inclusive moves suggests we do not have sufficient data to accurately characterize these moves in this context. Prior work characterizing teaching moves considered inclusive moves to be talk that gave all students a voice in whole-class discussion (Grinath & Southerland, 2019). As we limited our data set to OE–small group interactions, the paucity of inclusive moves is not surprising. In groups of two or three students, it would be unusual for OEs to enact moves to ensure all voices are heard.

4.1.2 | Novel talk moves

In addition to the ambitious talk moves observed in science education contexts (Grinath & Southerland, 2019; Windschitl et al., 2012, 2018), we observed OEs utilize design check-ins and revoice tangible manifestations of students' ideas. These talk moves have not yet been described in the literature and may be specific to an engineering outreach context.

Design check-in

We characterized a design check-in as an open-ended question or statement that provided opportunities to surface students' design ideas without specifically referencing a group's design. Design check-ins functioned as gentle invitations to students to voice their design ideas and signaled that students' ideas about design mattered.

We present two vignettes from one engineering design challenge session; each vignette illustrates a design check-in followed by a student voicing and demonstrating their team's design ideas. Tables 3 and 4 show these design check-ins. In this challenge, fifth graders Jordan and Lucy (all names are pseudonyms) attempted to use LEGO gears and bricks to build a machine that could dig through soil. In the first vignette, the students were brainstorming ideas about what kind of digging motion and mechanism to use, when OE Katya approached.

We use the following transcription conventions: [ ] indicates editorial comments about actions or missing words, italics indicate stress on a word or syllable; … indicates a speaker's words are omitted; / / indicates overlapping talk; and – indicates a pause or self-interruption.

In Line 4 (L4), Katya initiated talk with Jordan and Lucy with a display question. Jordan and Lucy both responded briefly ("Yeah") to Katya's closed-ended question (L5 and L6). Katya seemed to want a more expansive response because she invited the students to say more with a design check-in, saying, "Talk to me" (L8). Katya did not specify that she wanted the students to talk about their design ideas, but Jordan took Katya's statement as an opportunity to talk about and demonstrate what and how the team intended to build (L9).

TABLE 3 Design check-in: "Talk to me."

Line	Speaker	Transcript	Move type
1	Jordan	Or we could make this go like that [Jordan spins a LEGO piece] and rotate like that so it digs – [Jordan mimes rotation with his hands.]	
2	Lucy	Oh yeah.	
3	Jordan	– the dirt from the ground. So take – Oh, we can connect another one right here like that [Jordan sketches] so then it's gonna rotate like that but this is still gonna face down and then the big one – this [Jordan taps a LEGO piece] –	
4	Katya (OE)	So do you guys have your thing planned up?	Conservative: Display question
5	Jordan	Yeah.	
6	Lucy	Yeah.	
7	Jordan	So we're gonna use –	
8	Katya	All right. Talk to me.	Ambitious: Design check in
9	Jordan	So maybe we're gonna use this for the rotator, then uh, I think it was this one. [Jordan picks up two LEGO pieces.] Gonna connect this. [Jordan tries to connect two LEGO pieces.] Oh, it doesn't fit.	
10	Katya	I think you might need a different type of connector.	Conservative: Minilecture

TABLE 4 Design check-in: "How's it going?"

Line	Speaker	Transcript	Move type
11	Jordan	So this would be the rotator and it would go like that. [Jordan demonstrates a crank he has built.]	
12	Lucy	Oh, OK. Yeah. But then would this – [points to crank]	
13	Jordan	But this would be the rotator – this would be the rotator. [Jordan shows Lucy how a piece of the crank unit turns.]	
14	Lucy	OK, yeah.	
15	Jordan	So that would be – or maybe we could go connect – is there another one? This [LEGO piece] with that [LEGO piece]. Now we have to make it – that. That doesn't work. We need to find a way to – will this work? We need to find something. So –	
16	Margo (OE)	How's it going?	Ambitious: Design check in
17	Lucy	Good.	
18	Jordan	We're trying to find a way to like, make this [crank] turn like that. [He rotates a crank.]	
19	Margo	OK.	Other
20	Jordan	Make it turn like that and then have something connected to this [he picks up a gear] so that it turns like that [he rotates the gear horizontally] and then this [he picks up a LEGO beam] would be like the digger.	

After Katya encouraged Jordan to find a different LEGO connector (L10), she left. Jordan and Lucy talked about possibilities for their design for 2 min, after which OE Margo approached (L16, below).

OE Margo used a design check-in, asking, "How's it going?" (L16). Lucy's response, "Good," (L17) was ambiguous, but Jordan took Margo's question as an invitation to communicate the team's design ideas. Jordan demonstrated and described how their crank functioned and shared the team's envisioned ideas for a design component (L18 and L20).

In these vignettes, we saw design check-ins elicit a student's design ideas. In both instances, it would have been possible for students to have taken up the OE's check-in as something other than an invitation to share design ideas. Jordan and Lucy could have taken "Talk to me" as a directive to expand on their answers to Katya's prior display question about their plan and could have responded, "We've finished planning." They could have taken "How's it going?" as a general question about their progress in the challenge and responded, "Fine" or "Terrible." However, Jordan responded to Katya's statement "Talk to me" (L4) and Margo's question "How's it going?" (L16) by describing and demonstrating ideas about the team's design solution, indicating that the OEs' moves made space for students to share their design ideas.

Although we did not anticipate that "Talk to me" or "How's it going?" would elicit students' design thinking, we noticed that in most cases, students took design check-ins as opportunities to discuss their design ideas and reasoning. As such, we conjecture that a design check-in is an ambitious talk move that may indicate an OE's interest in students' design ideas and encourage students to communicate those ideas. The potential of the design check-in to convey to students that their ideas and their peers' ideas are important suggests that the design check-in could be a productive engineering educator talk move that supports students' epistemic authority.

Revoicing tangibly manifested ideas

Revoicing is typically conceptualized as the act of an educator rephrasing or making an inference from a student's verbalized ideas (Grinath & Southerland, 2019; Michaels et al., 2008; O'Connor & Michaels, 1993). We observed a novel form of revoicing; wherein OEs reflected students' tangibly manifested ideas. Outreach educators revoiced student ideas not only by rephrasing or interpreting students' speech, but also by voicing what the OE noticed about students' ideas as manifested in their design artifacts, including sketches, solution artifacts-in-progress, and built solutions. In these moves, OEs did not insert their own design ideas; rather, they reflected and verbalized students' ideas.

In Table 5, we present an OE revoicing ideas encapsulated in a student team's build and sketch. In this challenge, fourth graders Darlene and Helena were using craft materials to build a water filter. OE Lyla approached as Darlene and Helena were twisting pipe cleaners together to form one layer of their filter.

TABLE 5 Revoicing ideas manifested in design artifacts.

Line	Speaker	Transcript	Move type
1	Helena	Why don't we make them [pipe cleaners] into loops? [She bends a pipe cleaner into a loop.]	
2	Lyla (OE)	Ooh, nice. Oh, you're gonna make like a, kinda like a weaving thing for the water to go through? That's a really good idea.	Ambitious: Revoice
3	Darlene	Yeah … And this [pointing to a polystyrene foam block] could catch, um, a lot of the uh chemicals and stuff. … It looks good so far. We might need to get more materials, though. …	
4	Helena	We're probably gonna change a lot of stuff.	
		[Omitted: discussion relating this design challenge to a prior challenge]	
5	Darlene	Yeah, our thing is kind of complicated. [She shows her planning sketch to Lyla.]	
6	Lyla	Oh wow, you got a lot of layers there, yeah.	Ambitious: Revoice

When revoicing a student's spoken idea, an educator may infer a meaning of the student's speech and offer the student an opportunity to confirm or contradict the educator's interpretation and extend the conversation (O'Connor & Michaels, 1993). In this vignette, Lyla revoiced student ideas as she interpreted them from physical representations. In Line 2, she revoiced an idea embodied in the team's built artifact; in Line 6, she revoiced an idea represented in a student's sketch. Engineering design involves creating or improving a product or process, and as such, engineering students often create a physical artifact as part of their learning. We conjecture that ambitious engineering instruction includes recognizing student ideas embedded in student-designed, tangible artifacts, in addition to recognizing ideas embedded in students' speech.

4.2 | Opportunities afforded by ambitious and conservative teaching talk moves

Underlying the call for ambitious instruction is the premise that it situates students in contexts that promote participation in disciplinary practices. While we would like to connect ambitious teaching moves with students' participation in specific engineering practices, that is outside the scope of this analysis. Here, we provide evidence that OEs performed a variety of ambitious talk moves that afforded opportunities for students to engage in engineering design. Specifically, these moves opened spaces for students to reason and reflect about their designs through engagement in sensemaking, mechanistic reasoning, and reflective decision-making. Additionally, we offer evidence that at times and contrary to our expectations, OEs enacted conservative moves that made space for students to engage in engineering design. Below, we present two intensity cases to illustrate these opportunities.

4.2.1 | Ambitious moves centered students' ideas

Ambitious moves foregrounded or promoted student thinking about engineering design, inviting students to share their ideas or opening space for students to discuss their ideas. In the first intensity case, we present examples of an OE employing three types of ambitious moves: probing, pressing, and revoicing. In this engineering challenge, student teams used craft materials to create a filter to remove food dye and macroscopic debris from water. Prior to the dialogue below, fourth graders Darlene and Helena had selected materials to use and reasoned that they wanted materials that would "get the big stuff," "get the little stuff," and not "soak up the water." They sketched design ideas and wrote a materials list in individual design notebooks, then called to OE Fatima to share their sketched solution ideas and materials lists. We present the dialogue of this first intensity case in Table 6.

After Darlene and Helena listed materials and their order in the design, Fatima could have acknowledged their design plan as complete and ended the interaction after Line 8. However, ending the conversation at that point could have suggested to the students that the main goal of the challenge was choosing materials. Instead, Fatima continued to talk with the students about their design using a probing question (L9) that opened space for these students to voice their reasoning and justify their choice of materials. In response, the students explained that certain materials would soak up some of the contaminants in the water (L10–14).

TABLE 6 Ambitious moves: Probe, press, and revoice.

Line	Speaker	Transcript	Move type
1	Helena	[Pointing to her design notebook] So we have pipe cleaners first, then we have popsicle sticks, then tape, then coffee filters, then felt, and then fabric at the bottom so it doesn't leak.	
2	Fatima (OE)	Ooh. Wow, that's really good. I like it a lot.	Conservative: Evaluate
3	Fatima	[Points to Darlene's design notebook] And do we have the same thing over here? Same design?	Conservative: Display question
4	Helena	Yep.	
5	Darlene	Yep. Same thing but it's kind of different.	
6	Fatima	Awesome, yeah.	Other
7	Helena	‘Cause we're gonna plan our like –	
8	Darlene	It's not very different, but it's kind of different. [Darlene and Helena laugh.]	
9	Fatima	That's OK. All right, so do you want to talk to me really quickly about which materials you think are – are gonna filter out which particles?	Ambitious: Probe
10	Darlene	I think that the pipe cleaners and the popsicle sticks and maybe also the coffee filters are gonna soak up like, all, like, the chemicals in the water –	
11	Helena	And paper. [The challenge includes removing paper shreds from the water.]	
12	Darlene	And the paper and stuff.	
13	Helena	And then, I think the –	
14	Darlene	And the Styrofoam too, because it's – [Looks at her notebook]. We don't have Styrofoam on here [their materials list].	
		[Omitted: Fatima reassures students they can use Styrofoam.]	
15	Helena	We can put a layer of Styrofoam with the felt.	
16	Darlene	Good idea. But should the felt go on top or the bottom?	
17	Helena	It doesn't really matter. We're planning.	
18	Fatima	So what do you think the felt and the fabric are going to do?	Ambitious: Probe
19	Helena	Um, make sure all of the food coloring – only clean water comes out.	
20	Darlene	/‘Cause you don't want to drink it [the food coloring]./	
21	Fatima	/Yeah, so yeah, that's a really/ good point. So, we think that the felt is gonna catch that food coloring, it's not gonna pass through that barrier?	Ambitious: Revoice or reflect
22	Helena	It might.	
23	Darlene	[Nods affirmatively]	
24	Fatima	It might.	Inclusive: Repeat
25	Helena	But just a little bit.	
26	Fatima	A little, yeah. So why do we think the felt is gonna be more likely to catch the food coloring?	Ambitious: Press for explanation
27	Helena	Because it's thicker.	
28	Fatima	Because it's thicker. That's a good point. And what – what does it do when water passes through it? /It – it kind of soaks it up, right?/	Conservative: Minilecture
29	Helena	/It soaks it up./ Like a sponge.	
30	Fatima	Yeah, like a sponge. Great point, you guys.	Conservative: Evaluate
31	Helena	Why don't we have sponges?	
32	Fatima	Why don't we have sponges?	Inclusive: Repeat
33	Helena	Well, that would actually soak up the water.	
34	Darlene	‘Cause it's like the same thing as the Styrofoam but the Styrofoam has more holes in it, so a lot of it [water] can go through, but not bigger, um, the bigger chemicals and stuff.	

(Continues)

TABLE 6 (Continued)

Line	Speaker	Transcript	Move type
35	Fatima	Mmm. So is Styrofoam absorbent, do we think?	Conservative: Display question
36	Darlene	It's only absorbent to the – to the chemicals and stuff.	
37	Helena	I think it might help with the dirt a little bit.	
38	Fatima	You think it might help with the dirt a little bit? Why is that?	Ambitious: Press for explanation
39	Helena	Because, like, it can get stuck – stuck in all those little crevices. Because the Styrofoam is just made up of tiny balls.	
40	Darlene	But what about the leaves? But what about – the leaves would probably get stuck in the felt.	

Fatima's next probing question (L18) encouraged the students to explain the function of their chosen materials to justify their choices. Helena's and Darlene's responses suggested that felt would allow only water to pass through (L19), achieving their goal of removing food dye from the water (L20). Fatima's revoicing (L21) enabled her to confirm her understanding of the students' reasoning and provided an opportunity for Darlene and Helena to confirm or contradict Fatima's interpretation (L22 and L23). Fatima continued to make space for the students to reflect on their design and pressed the students to elaborate on their mechanistic reasoning (L26, L38), eliciting additional discussion about material properties of felt and Styrofoam and how those contributed to removing contaminants (L27, L29, L39, and L40).

Fatima's ambitious moves made space for Darlene and Helena to reason about materials and mechanisms. This case illustrates ways OEs' ambitious talk moves can open opportunities for students to make progress in engineering design and highlights that ambitious moves center sensemaking about students' ideas.

4.2.2 | Conservative moves stabilized participation

In science classrooms, conservative moves have been conceptualized as less supportive of students' disciplinary engagement than ambitious moves (Grinath & Southerland, 2019; Stroupe, 2014). However, recent research has called for greater attention to the affordances of direct instruction in engineering education (Vossoughi et al., 2021), and we saw moments when conservative moves appeared supportive of students' disciplinary engagement and progress. We observed OEs use conservative moves when they noticed students encounter a technical or affective obstacle; in these instances, OEs provided technical information or emotional reassurance and encouragement to help students progress with their designs.

The second intensity case highlights an OE using conservative moves in both of these ways. In this design challenge, fourth graders Wren and Ximena chose to improve car visibility and to build a miniature model of a car that would light up. Wren and Ximena became stuck at two points: they struggled to join cardboard components of their design solution and they struggled to light an LED.

In the first segment, Ximena and Wren started to build a cardboard car body, successfully joining two sides with duct tape. They struggled to attach the bottom of the car to the sides. Ximena held the cardboard while Wren unsuccessfully tried three times to tape the cardboard pieces together, stating matter-of-factly, "That did not work" and "This tape is not sticky at all." OE Fern sat down with the team, and Ximena and Wren described the problem they had chosen to solve and their envisioned solution. Then, the dialogue in Table 7 began.

Fern left, Wren adjusted the tape on the car body, and then Ximena and Wren began building the light-up element of their car. They attempted to light an LED with a 9-volt battery, wires, and conductive modeling dough. Ximena wrapped a wire around a battery terminal and attached dough to the battery. Wren added the LED, but it did not light. She tinkered unsuccessfully with the LED, and both Wren and Ximena expressed frustration, saying "Seriously?!," "This is terrible," and "Why isn't it working?" as they continued to troubleshoot the circuit. Wren called to Fern for help, and Fern returned. The interaction is given in Table 8.

We identified these moves as conservative because they elicited an anticipated answer or delivered information; unlike ambitious moves, they did not encourage student reasoning. However, we noticed that these moves provided opportunities for students to make progress in engineering. When Wren and Ximena told Fern they could not attach a

TABLE 7 Conservative moves support technical progress.

Line	Speaker	Transcript	Move type
1	Fern (OE)	So what is your plan?	Ambitious: Probe
2	Wren	I can't find a way to get this [piece of cardboard] to attach.	
3	Ximena	Yeah.	
4	Fern	OK, I think tape is probably the best way to go about it.	Conservative: Minilecture
5	Ximena	We tried, but it does not work.	
6	Fern	Why not?	Ambitious: Press
7	Ximena	It just like doesn't.	
8	Wren	So I like put it [tape] here and then I put it [tape] into the corners, but then it unstuck.	
9	Fern	OK, so what might help is just putting it [tape] over from the bottom to the side on each side.	Conservative: Minilecture
10	Fern	All right? Can I get you more – some more duct tape?	Conservative: Process management
11	Ximena	Yeah.	
12	Fern	All right, I'm going to go do that.	Conservative: Process management
		[Omitted: Student conversation about a popular song. While Fern searches for tape, Wren trims the bottom of the car and Ximena removes conductive dough from the terminals of a 9-volt battery.]	
13	Fern	All right, so here is some duct tape. I would definitely put some on the bottom. Here. What I would do is I would flip it over like this [Fern turns the cardboard car body over] and then we can just kind of go like this. [Fern tapes a piece of cardboard to the car body.] And then do the same thing with the other side. [Fern adds a second piece of tape.] Now it's taped on three sides and it should be pretty stable. Sound good?	Conservative: Minilecture
14	Ximena	OK.	
15	Wren	Thanks.	
16	Fern	OK, awesome. I really love your idea. You're doing great work. I'll be back to see it later.	Conservative: Evaluate

piece of cardboard (L2 and L3), Fern responded with a minilecture and suggested they use tape (L4). Had the students not already tried tape, Fern's suggestion could have provided knowledge of materials. Since the students had tried tape, Fern's suggestion could have been taken up by the students as reassurance that their attempts to secure the cardboard with tape would eventually succeed. However, Ximena and Wren pushed back on Fern's suggestion and explained that they had unsuccessfully tried tape to fasten the cardboard (L5, L7, and L8). Fern responded with a series of minilecture and process management moves. She described another method for using tape to fasten the piece of cardboard (L9), offered to get tape for the students (L10 and L12), and demonstrated her method of attaching the cardboard (L13).

These conservative moves supported Wren and Ximena to make technical progress and continue building, rather than remain stymied by one step in their process. We could imagine Fern taking an ambitious approach where she pressed Wren and Ximena to think about other ways to get the tape to stick or other fastening methods. This hypothetical ambitious route could have afforded Wren and Ximena with opportunities to reason about and construct knowledge about fasteners. However, Fern's conservative moves supported the students to progress to a new element in their envisioned design solution, rather than spend their limited time struggling with construction. We do not argue that this conservative path was pedagogically ideal, but we do see value in Fern choosing to help these students move past a material obstacle so they could realize their envisioned solution.

These moves also supported students in making affective progress. Fern invited Ximena and Wren to identify the frustration point and to utilize her as a resource (L17, L18). While Fern's response (L19) was potentially ambiguous, we argue that in this context, this move evaluated the students' product or process and served to reassure the students that their progress was acceptable and normative. Fern opened space for these students to experience failure as a typical

TABLE 8 Conservative moves support affective and technical progress.

Line	Speaker	Transcript	Move type
17	Fern (OE)	All right. What's going on? How can I help?	Conservative: Process management
18	Wren	We can't make this [circuit] work.	
19	Fern	That's OK.	Conservative: Evaluate product or process
20	Ximena	It's, like, impossible.	
21	Fern	All right, I can tell you that – the problem right now. What's going on is right now, this is – the electrons are going out of this terminal, this end, through the playdough and right back. Even when you connect, like, an LED to it, it's doing what's called short circuiting. So it's going right from here [terminal] to here [terminal], it's not taking any detours to go to your LEDs. [Fern points to the terminals and the dough while she is speaking, sliding her finger to mime the electron path.]	Conservative: Minilecture
22	Wren	Oh.	
23	Fern	So, if you split it up and you did something like this – [Fern breaks the dough into two pieces and connects one to each battery terminal.]	Conservative: Minilecture
24	Wren	And then we attach the wires to the playdough?	
25	Fern	Yep, that would probably help you a lot, OK?	Conservative: Minilecture
26	Wren	OK. Thanks.	
27	Fern	Sound good?	Conservative: Display question
28	Wren	Yes.	
29	Fern	There you go. [Fern leaves.]	Other
30	Ximena	Here, let's fix this [circuit]. [Ximena and Wren rebuild the circuit.]	
31	Wren	Wait, they're touching. [Wren moves a piece of conductive dough.]	

element of the engineering design process and recruiting technical assistance as a legitimate engineering action. Fern delivered a series of minilectures (L21, L23, and L25) about building a circuit with the materials at hand, and this information supported Ximena and Wren to move through a stuck point and focus on their design. Fern used a display question to determine whether the students believed they were able to move forward with their design (L27), after which Fern left. Ximena and Wren continued to troubleshoot the circuit and add elements to their car, even persisting for 8 min after being directed to stop building for the whole-class share-out.

This case illustrates a series of conservative talk moves, which together afforded Ximena and Wren affective and technical progress. Fern offered assurance that the students' actions and emotions were appropriate in the discipline and offered a path for the students to make progress in addressing the functional requirements of the design challenge. While Fern's conservative moves did not support students to reason and sense-make the way ambitious moves could, they did make space for students to develop or draw on the engineering habits of mind of optimism, persistence, and collaboration (AE3 & ASEE, 2020). This case offers evidence of the potential for conservative moves to support students' productive participation in engineering design.

5 | DISCUSSION AND IMPLICATIONS

Our findings are formative in (1) characterizing engineering outreach educators' discourse, (2) identifying talk moves that are likely to support student participation and progress in engineering design, and (3) initiating conversation about the nature of ambitious engineering teaching. We first discuss the need to characterize the nature of ambitious engineering teaching, and then we discuss the OEs' discourse, connections to student participation, and implications for research and practice.

5.1 | What is ambitious engineering teaching?

This work surfaces questions about the nature of ambitious engineering teaching. We point toward a potential alignment between ambitious science teaching goals of supporting students to "do science" and engineering outreach goals of helping students to "do engineering" (Jiménez-Aleixandre et al., 2000). We posit that ambitious practices may be a useful framework to guide engagement in authentic engineering activities (Bers & Portsmore, 2005; Bledsoe et al., 2004; Portsmore et al., 2003). We also note that engineering is a discipline in its own right; while engineering education shares much in common with science education (AE3 & ASEE, 2020; Cunningham & Kelly, 2017; NGSS, 2013), there are fundamental differences in disciplinary participation, namely creating design ideas and solutions versus creating explanations for natural phenomena. Thus, engineering teaching merits its own, discipline-specific characterization, which takes into account goals for learners to generate, reflect upon, and revise design problems, ideas, and solutions.

To that end, we explored a preliminary framework for characterizing engineering outreach educators' discourse, grounding our exploration in principles of ambitious teaching and norms of engineering education (AE3 & ASEE, 2020; Capobianco et al., 2018; Grinath & Southerland, 2019; Windschitl et al., 2012, 2018). In addition to identifying alignment with ambitious science teaching, we identified two novel ambitious moves specific to engineering: a design check-in, or invitation for students to share their ideas, and a form of revoicing focused on students' design artifacts, rather than their speech. In OEs' use of the ambitious moves probing and pressing, we observed OEs attending to the ideas represented in students' sketches and builds. Educators' attention to the tangible artifacts characteristic of engineering is further evidence that engineering teaching warrants nuanced, discipline-specific description.

5.2 | Characterizing outreach educators' discourse and connecting it to student participation

This work contributes to understanding the ways that engineering outreach educators facilitate student participation through talk. Our data suggest that OEs employ varied talk moves that encourage students to participate in engineering in multifaceted ways. While reasonable to expect that ambitious teaching moves support students' engineering learning, ambitious moves may not be exclusively supporting students' participation in engineering design. Ambitious and conservative talk moves, we conjecture, serve varied pedagogical goals and can both be productive for students.

In this engineering context, we observed ambitious teaching moves previously identified as supporting science learning in science education contexts (Grinath & Southerland, 2019; Michaels & O'Connor, 2012; Windschitl et al., 2018). However, while we agree that in some situations, conservative moves do little to support student learning, we also see potential for conservative moves to offer support to students. Consider OE Fern's dialogue with Wren and Ximena: when Fern provided information (a conservative talk move), she opened a path for the students to continue their work and advance their design. Additionally, when Wren and Ximena expressed frustration, Fern reassured them that their emotions were normative within the engineering context, supporting them to persist through a challenge and to consider their feelings of frustration to be acceptable.

Our findings suggest that conservative moves do not always shut down sensemaking but can support students to bypass a technical or emotional obstacle and make technical or affective progress. Removing a technical obstacle makes space for students to advance toward realizing their envisioned design solution. Characterizing struggle and frustration as integral to engineering supports students to perceive their own experience as normative, which encourages participation and persistence in a discipline or endeavor (Elliot & Dweck, 2005; Godwin & Potvin, 2017; Jaber & Hammer, 2016a, 2016b; Marra et al., 2012; Radoff et al., 2019).

At times, display questions could be considered "inauthentic questions"—questions an educator already knows the answer to (Nystrand & Gamoran, 1991) that constrain interactive or ambitious teaching. However, we see many of these questions as necessary and productive parts of interactive engineering experiences. Display questions can be a way for educators to quickly ascertain a student's familiarity with a concept, material, or tool, or to identify a student team's status in the team's design process, providing educators with information needed to adapt instruction.

The evaluate talk move has traditionally been considered an unproductive teaching move, largely because of its effect in the constraining initiate-respond-evaluate (IRE) classroom discourse sequence (Cazden, 1988; Mehan, 1979b), closing off opportunities for student thinking in whole-group discussions (Alozie et al., 2009; Mehan, 1979b; Nassaji & Wells, 2000; Nystrand & Gamoran, 1991). The IRE talk pattern is problematic because it suggests to students that success hinges on quickly producing a singular, correct answer (Mehan, 1979a). IRE is at odds with goals of engineering education, where we strive for solution diversity: we want students to produce many possible solutions to a single problem (LEGO Education, 2014; Willner-Giwerc et al., 2020). In our data, we did not see evaluative moves occur in a typical IRE sequence. Rather, we saw educators use evaluative moves in ways that encouraged students to extend their thinking. The overwhelming majority of these moves were affirming (e.g., "That's a good idea. I support that.") and seemed to encourage students to continue with their design trajectory.

Similarly, minilectures or suggestions appeared to redirect students toward a more likely trajectory of success. In this context, educators used minilectures to deliver just-in-time information that students needed to make technical progress. They frequently delivered this information as design suggestions, leaving space for students to make their own decisions about how to proceed.

Our findings suggest that, at times, conservative moves supported students to re-engage with design decisions, reflect on design solutions, or remove a technical barrier to more substantive design work. Conservative moves could support students' agency to build on their own ideas and students' affective relationship with engineering. Our findings are consistent with research in informal learning spaces, such as makerspaces, that suggests selected instances of direct instruction can support youths' technical progress and sense of agency (Vossoughi et al., 2021). In addition, research suggests that acknowledging students' affective experiences while engaging in a discipline can stabilize students' disciplinary participation and support continued participation (Jaber & Hammer, 2016a, 2016b). In an engineering outreach context, we envision conservative moves as stabilizing both students' affective relationships with and participation in normative engineering practices.

5.3 | Engineering outreach may encourage ambitious moves

Our findings suggest that the nature of engineering outreach may have supported novice educators to organically enact ambitious moves. The program staff who led the training for OEs did not deliberately model ambitious teaching; however, the training did orient OEs toward a program goal of encouraging students' agentive participation in engineering design. The OEs typically interacted with students in casual, friendly ways and frequently positioned themselves as near-peers or co-learners with students, rather than as authorities. This co-learner positioning might have contributed to creating a culture in which OEs signaled that they wished to understand students' designs and in which students perceived design check-ins as authentic questions (Nystrand & Gamoran, 1991) aimed at understanding their designs. This conjecture is consistent with other work that has observed educators' positioning as peers to support co-learning interactions and students' epistemic authority (Gartland, 2014; Halim et al., 2021; Vossoughi et al., 2021).

Although revoicing, probing, and pressing are typically associated with experienced educators or educators who have participated in professional development focused on accountable talk or ambitious talk (O'Connor & Michaels, 1993, 2019; Stroupe, 2014), the materiality and open-ended nature of engineering design may have afforded the novice OEs opportunities to perform these ambitious moves. The tangibility of design artifacts likely supported OEs to notice and foreground students' physically manifested ideas, and the emergent and varied nature of students' design solutions may have focused OEs' attention on identifying students' ideas (Watkins & Portsmore, 2021). In contrast to the ways in which rigid interpretations of a discipline have inhibited novice educators from attending to students' ideas (Singer-Gabella et al., 2016), this program's focus on open-ended problems, iteration, and diverse solutions may have helped these novice OEs attend to students' ideas through ambitious interactions.

5.4 | Limitations

We note two methodological limitations and two limitations of the framework. We have not attempted to characterize teaching moves in all engineering education contexts. We emphasize that we observed novice educators in an outreach context that foregrounded engineering; schoolteachers who need to incorporate science and engineering closely together during instruction may use a different set of teaching moves. We did not collect demographic information about OEs other than gender and we did not analyze discourse with a gender-aware lens; as such, we cannot comment on how gender or additional identities might have influenced OEs' interactions with students. It is possible that teaching moves differ across varied contexts.

Although we see ambitious instruction as a fruitful framework for characterizing engineering outreach educators' teaching moves, we found constraints in thinking of teaching moves as ambitious, conservative, or inclusive. While ambitious moves appear to be especially useful in terms of providing students with opportunities to sense-make, that does not mean we should think of conservative moves exclusively as shutting down opportunities to learn. We observed conservative moves that provided opportunities for students to continue participating in engineering activities in the short term; however, it was beyond the scope of this study to connect conservative moves with long-term technical and affective outcomes for students. Notably, the category of inclusive moves was inconclusive, as our data set was limited to OEs' interactions with small groups, while in the framework that inspired our coding, inclusive moves were conceptualized as talk that gave all students a voice in the whole-class discussion (Grinath & Southerland, 2019). It is possible that observation of whole-class engineering instruction could yield more examples of inclusive moves; it is also possible that we may need to reimagine what inclusive talk means in small group interactions.

5.5 | Implications

Given the prevalence of engineering outreach, it is encouraging that our data suggest that these novice outreach educators demonstrate productive beginnings of pedagogical talk moves that center students' ideas and agency as well as talk moves that may stabilize students' participation in engineering design. Our findings suggest outreach educators are capable of enacting progressive engineering teaching and supporting students to engage in ambitious learning. However, additional research is needed to better understand students' uptake of these moves, the influence on students' affective relationships with engineering, and ultimately, the consequences to students' short- and long-term participation in engineering. In addition, research is needed to design effective pedagogical training for outreach educators.

Our process of characterizing engineering educators' discourse highlighted ambitious talk moves grounded in goals and activities particular to engineering. We contribute an initial set of engineering-specific talk moves to the ambitious teaching framework and add to extant work in elementary engineering education and ambitious teaching (Capobianco et al., 2018; Windschitl et al., 2012). Our work highlights the need to attend to and further explore educators' attention to physical artifacts and builds as representations of students' thinking (Dym et al., 2005; Roth, 1996). Future work should investigate interactions between educators' attention to students' artifacts and how such attention could support students' engineering sensemaking.

Finally, while the ambitious science teaching framework offers useful structures to characterize engineering outreach teaching talk moves, we raise the question of the utility of conservative moves in engineering outreach. While ambitious moves promote student thinking, our work points to the potential for select conservative moves to support technical and affective progress. Future work is needed to continue to unpack engineering educators' talk moves that not only scaffold technical learning goals but also support students' affect and identity (Capobianco et al., 2018; Vossoughi et al., 2021).

6 | CONCLUSION

As precollege engineering outreach continues to proliferate, insight into educator discourse is essential to informing the preparation of educators to enact pedagogical approaches that encourage engineering learning. This paper describes engineering outreach educators' teaching moves and points to outreach educators' capability in using ambitious moves. Ambitious engineering instruction may be a useful framework for designing engineering outreach to support students' participation and progress in engineering design. Additionally, conservative teaching moves, typically considered constraining, may support productive student affect and engagement in engineering design. Examination of the implementations and impacts of teaching moves across engineering education contexts will be important to better prepare educators to enact progressive, equitable, and impactful pedagogical approaches.

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APPENDIX A

TABLE A1 Characteristics of engineering outreach educators.

Name	Semesters in outreach program	Engineering major	Gender
Barbara	1	Y	F
Dahlia	3	Y	F
Deana	1	N	F
Fatima	1	Y	F
Fern	2	Y	F
Katya	3	N	F
Kevin	1	Y	M
Lyla	1	Y	F
Margo	6	N	F
Melanie	5	N	F
Nancy	3	Y	F
Nico	2	Y	M
Olympia	1	Y	F
Quimby	4	N	M
Simon	3	Y	M
Steve	1	N	M
Tejaswi	3	Y	F
Xander	2	Y	M

Note: Names used here are pseudonyms. Semesters in outreach program indicates the number of semesters the outreach educator had participated in the program at the time of data collection. Y/N indicates if the outreach educator majored in engineering (Yes or No). F/M indicates female or male gender; none of the focal educators expressed non-binary identities.

APPENDIX B

TABLE B1 Video data set characteristics.

Group	School and grade	Outreach educators	Students	Engineering design challenge
Group 1	Cherry, Grade 4	Olympia and Simon	Beto, Bill, and Keith	Design and build an air-powered rocket that reaches a target using craft materials
Group 2	Sycamore, Grade 5	Katya and Margo	Jordan and Lucy	Design and build a digging machine using LEGO gears and bricks
Group 3	Cherry, Grade 4	Dahlia and Steve	Diana and Henry	Create a music box using LEGO NXT robotic components
Group 4	Elm, Grade 4	Fern and Xander	Wren and Ximena	Improve car safety and build a model using electronic and craft materials
Group 5	Willow, Grade 5	Nancy and Tejaswi	Bella and Bonnie	Design and build a model home to withstand simulated natural disasters using craft materials
Group 6	Cherry, Grade 4	Olympia and Simon	Denise, Karina, and Leslie	Design and build an air-powered rocket that reaches a target using craft materials
Group 7	Cherry, Grade 4	Barbara and Melanie	Janelle and Octavia	Create a terrible drum using craft materials
Group 8	Cherry, Grade 4	Barbara and Melanie	Liam and Janelle	Create an optimal drum using craft materials
Group 9	Willow, Grade 5	Deana and Nico	Betty and Marisol	Design and build a chair for a stuffed toy using LEGO bricks
Group 10	Willow, Grade 5	Kevin and Nico	Daisy and Natalie	Design and build a chair for a stuffed toy using LEGO bricks
Group 11	Elm, Grade 4	Fatima, Lyla, and Quimby	Darlene and Helena	Create a filter to remove dye and macroscopic particles from water using craft materials
Group 12	Willow, Grade 5	Nico	Daisy and Kate	Create a filter to remove macroscopic particles from water using craft materials

Note: Table B1 describes the data set of the 12 focal groups. All names are pseudonyms which respect the gender of individual participants. To protect the anonymity of participants and also acknowledge the ethnic diversity of participants, we randomly assigned pseudonyms from a list which included a range of culturally-connected names which respected the ethnicities and nationalities of participants.

APPENDIX C

TABLE C1 Analytic approach.

Coding cycle	Data sources	Codes	Coding process
1	Groups 1–2	Modified and expanded codes from Grinath and Southerland (2019)	Collaborative
2	Groups 3–6	Refined codes to create interim codebook	Independent coding; reconcile through discussion
3	Groups 7–10	Refined codes to create final codebook	Independent coding; reconcile through discussion
4	Groups 1–6, 11–12	Final codebook	Independent coding; reconcile through discussion

APPENDIX D

TABLE D1 Codebook.

Code category: Code	Definition	Examples
Ambitious: Ambitious engineering teaching moves invite, foreground, or promote student thinking about engineering design or engineering science. These moves invite students to share (say or show) ideas or open space for students to discuss their ideas or peers' ideas.		
Design check-in	An open-ended question or statement that does not specifically reference a group's design, yet offers students the opportunity to talk about or show their design ideas.	How's it going over here? How's it coming along? What's going on? Talk to me.
Probing question	An open-ended question that focuses on a student's design ideas or thinking. A probing question serves to surface student ideas about their design, including their envisioned ideas, artifact, or testing results.	Can you guys tell me about your idea? What worked well about it [your design solution]? What's your next idea to make it better? What did you change between [this design solution] and [your earlier iteration]?
Press for explanation	A move which asks for student reasoning about their design. This move can occur in response to a student comment or a student design choice. The design choice may have been stated by the student or observed by the OE.	Why do you think that was happening? Why did you do that? Why is there a hole? Why do you think that plastic is not going to work well as a drum?
Revoice or reflect	Noticing and emphasizing a student's idea, via paraphrasing or repeating a selection of a student's design-related comment, or voicing what the OE notices the student is doing with their design (that is, revoicing an action into words). This is a selective or focusing talk move and excludes rote repetition and minimal encouragers such as "OK," "Mmhmm," or "Got it."	Student: When you tap on it, it might make a hole because you might put too much pressure. OE: Ooh, yeah. So your materials might break. Student A: We added duct tape [to our rocket]. Student B: So that it's a tiny bit heavier because [an earlier iteration] flipped and went off course. OE: So a little weight would help? Student: Somehow trying to get [a part of our design] to spin, I do not know. OE: [looks at the gear train the students built] So you have all these [gears that you connected] and these all kind of spin together, right?

TABLE D1 (Continued)

Code category: Code	Definition	Examples
Conservative: Conservative moves orient student attention to OE-preferred actions, ideas, or processes. These moves provide opportunities to stabilize students' participation in dominant ways of thinking, knowing, or feeling in engineering.		
Display question; display step, status, or information	A request for simple facts or identification of students' status in the activity. This move prompts for a report or a single correct answer.	Are you done making your drum? Do you need to test? When you launched [a rocket iteration], did it flip while it was flying? That [characteristic] was something y'all were looking for [in your design], right?
Evaluate product, process, or reasoning	Categorize response, product, or process as normative in engineering, useful in attaining a disciplinary goal, or productive for the student's affective stance (or as not normative, useful, or productive).	That's a good idea. I support that. I really love your idea. That's a good first design. But right now I think that's really cool, especially the way all of the different ones [gears] spin.
Minilecture or suggestion	Respond to student contribution by delivering content, in the form of a design-related suggestion, content about the activity, or disciplinary norms or behaviors.	I can tell you the problem. What's going on is right now, the electrons are going out of this terminal, this end, through the playdough and right back. So when you connect an LED to it, it's doing what's called short circuiting. Tin foil's really good for waterproofing. Try kinda seeing how different gears line up and how you can attach them. So something I like to do once you test is think about what was good, what wasn't so good, and then how you can fix the things that were not good.
Process management	Provide reminders about the activity, instructions, materials, or time. This includes generalized and specific offers of assistance from the OE. This includes asking if students have the materials they want or need. This includes specific recommendations to take turns.	Do you guys have your data sheet? Okay, so, first test. So mark it down where it [the rocket] went. How can I help? If you have leftover money this week, you can use it next week [to purchase building supplies].
Inclusive: Inclusive moves offer equitable participation and offer all students a voice in the discussion or hands on the build.		
Distribute participation	Provide an opportunity for additional students to contribute to the discussion or the design solution.	Yeah, and so what do you think of that idea [that your partner said]? [Your teammate] thinks that it might be too loose. What do you think of that? And what do you think about that design?
Acknowledge contribution	Indicate a student's contribution is valuable without indicating correctness or indicate listening and encouragement.	Student: Ours [our drum] will seem pretty high pitch. OE: Yeah, you think so? Student: It's going to explode! OE: Is it? I hope not. Hypothetical: OE looks at the build and says, "I see you used Riley's idea about waterproofing and Yael's idea about stability."
Repeat	Repeat student's contribution to ask for clarification, or to acknowledge a student's idea.	Student: Would this work? OE: Would that work? Student: I think because it's lighter. OE: Because it's lighter? Student: And if you put 'em on something, from what [my partner] said, they go up. OE: They go up.

(Continues)

TABLE D1 (Continued)

Code category: Code	Definition	Examples
Other		
Other	Utterances that do not fit this coding scheme, including filler words, unspecific feedback, and speech that is not design-related (such as small talk).	Awesome. Interesting. You guys got it. Please do not press any buttons [on the research recording equipment].

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