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RESEARCH ARTICLE

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Examining interactions between dominant discourses and engineering educational concepts in teachers' pedagogical reasoning

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Abstract

Background: Engineering's introduction into K–12 classrooms has been purported to support meaningful and inclusive learning environments. However, teachers must contend with dominant discourses embedded in US schooling that justify inequitable distributions of resources.

Purpose: Drawing on Gee's notion of discourses, we examine how teachers incorporate language legitimizing socially and culturally constructed values and beliefs. In particular, we focus on the discourse of ability hierarchy—reflecting dominant values of sorting and ranking students based on perceived academic abilities—and the discourse of individual blame—reflecting dominant framings of educational problems as solely the responsibility of individual students or families. We aim to understand how these discourses surface in teachers' reasoning about teaching engineering.

Method: We interviewed 15 teachers enrolled in an online graduate program in engineering education. Utilizing critical discourse analysis, we analyzed how teachers drew on discourses of blame and ability hierarchy when reasoning about problems of practice in engineering.

Results: Teachers drew on engineering education concepts to reinforce dominant discourses (echoing specific language and preserving given roles) as well as to disrupt (utilizing different language or roles that [implicitly] challenge) dominant discourses. Importantly, teachers could also retool discourses of ability hierarchy (arguing for a more equitable distribution of resources but problematically preserving the values of ranking and sorting students).

Conclusions: K–12 schooling's sociohistorical context can shape how teachers make sense of engineering in ways that implicate race, gender, disability, and language, suggesting a need to grapple with how discourses from schooling—and engineering culture—maintain marginalizing environments for students.

KEYWORDS

discourse analysis, K–12 teachers, pedagogical reasoning

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1 | INTRODUCTION

As K–12 engineering education expands, a growing body of work points to the potential disciplinary affordances for engineering to support more meaningful and inclusive learning (Martin & Wendell, 2021).This scholarship highlights how educators can draw from conceptual tools in engineering education—iteration and failure, focus on community-based problems, novelty and diversity of engineering practices—in ways that disrupt dominant narratives and inequitable schooling practices (e.g., Hegedus et al., 2014; Holly, 2021; Tan et al., 2019). Such disruptions hold powerful implications for the distribution of educational resources.

While this research provides promising portrayals of how engineering education can be shaped toward more equitable ends, there is also reason for caution. For one, research in higher education and at the professional levels points to the ways engineering culture harms those from marginalized communities (Faulkner, 2000; McGee, 2016, 2021). In addition, given the historical structures of school institutions and how these structures have (re)produced educational inequalities (Apple, 1982), the use of concepts in engineering education will be shaped by the sociopolitical contexts of K–12 schooling. For example, in our prior work, we observed how a teacher used the engineering design process to control how and when students could engage in engineering activities, restricting their agency and opportunities to learn (Watkins et al., 2021). Similarly, Wright et al. (2018) highlight how collaborative engineering design tasks amplified the risks of entrenched, racialized classroom management practices for African American students, constraining their access to the learning objectives. Further, Schnittka (2012) explored how a middle school teacher limited engineering learning opportunities for students in a "low" ability tracked classroom, reproducing discourses of hierarchy and access, explicitly distributing educational resources unevenly. In these cases, the conceptual tools of engineering were used by educators to reinforce inequitable practices and stabilize unjust distributions of educational opportunities.

Ultimately, engineering's integration into K–12 classrooms is not starting from a blank canvas; incorporating engineering learning into these spaces will require researchers, teachers, and students to contend with dominant discourses embedded in the foundation of formal schooling in the United States. By discourses, we draw on what Gee (1999) calls big "D" discourses, referring to how language is integrated with socially and culturally constructed values, beliefs, and ways of thinking, being, and interacting in communities. These discourses are used to make meaning of our experiences, making certain relations recognizable. For instance, hierarchy discourse in schools uses language, "high kids" versus "low kids," signifying the cultural values of sorting and ranking students according to "smartness" and providing (or withholding) resources based on this ranking. In Schnittka's (2012) findings, we see how this dominant discourse interacts with engineering to reinforce the unjust and inequitable distribution of learning opportunities. These examples highlight that engineering tools are never neutral—not in school settings nor in design situations—motivating the need to examine processes of engineering teaching and learning as political contexts (Gutiérrez, 2013).

In this article, we focus on how dominant discourses of K–12 US schooling surface in teachers' reasoning about teaching and learning engineering concepts. We examine 15 teachers' pedagogical reasoning about their engineering teaching practice, seeking to understand patterns in how their reasoning integrates specific discourses in K–12 schooling and the role that engineering concepts play in reinforcing or disrupting these discourses. By centering the sociopolitical in teachers' pedagogical reasoning, this work surfaces new dimensions for engineering education researchers and teacher educators to consider as they seek to integrate engineering design in K–12 schools.

2 | THEORETICAL FRAMING

In this article, we focus on teachers' pedagogical reasoning: the interpretations, elaborations, explanations, and justifications underpinning their decision-making in the classroom (Horn, 2020). We take a situative perspective (Horn & Garner, 2022) to consider how teachers' reasoning is linked to the cultural, historical, and sociopolitical contexts of their teaching. This perspective recognizes that pedagogical actions or routines—like designing a planning sheet for students' engineering or requiring sentence stems in design conversations—involve teachers' reasoning with different assumptions (e.g., about who is capable), interpretations (e.g., about what is important to emphasize in learning), and predictions (e.g., about what activities will succeed) about students, teaching, schools, and the discipline of engineering. Understanding what meanings or tools teachers draw on to reason about their pedagogical actions and responsibilities is therefore crucial for realizing more equitable visions of engineering teaching.

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In their pedagogical reasoning, teachers draw on and adapt tools across different contexts of their learning. Some contexts may be local, with tools such as school or department norms, concepts from a professional development or informal conversations with colleagues, or district policies (Stroupe, 2016). But research has also shown that teachers draw on tools from broader sociopolitical contexts of teaching. For instance, Louie (2020) documented how teachers drew on meanings from reform mathematics discourses, namely the emphasis on student agency to solve mathematics problems, alongside discourses from traditional mathematics schooling, namely the discourse of ability hierarchies—reflecting dominant cultural values of sorting and ranking students based on perceived academic abilities. Hierarchy discourse shaped how teachers supported students' agency, which afforded "high students" more opportunities to try their own strategies and share their thinking, but not the "lows"—the students positioned as less capable in mathematics (pp. 16–17). Another tool within teachers' broader sociopolitical context is the discourse of individual blame, which engages cultural values of individual responsibility to reflect the dominant view that educational problems are solely the responsibility of individual students or families. Philip (2011) discusses how commonsense ideas such as "kids would rather play than work" influenced a teacher's reasoning about student failure. Here, the discourse of individual blame shaped how this teacher initially allocated their attention—toward remediating students for their "poor choices" rather than reflecting on their instructional practice.

This work highlights how teachers' tool use is inherently political, that is, relating directly to arrangements of power and resources. It motivates deeper consideration of how teachers make meaning of and use new reforms—such as the introduction of engineering education concepts in K–12 classrooms—given that teachers' work is situated in historical structures of oppression within formal schooling institutions and an inequitable society (Apple, 2004). In this article, we are interested in how these two dominant discourses of K–12 schooling surface in teachers' pedagogical reasoning about engineering and how teachers draw on conceptual tools from engineering education in relation to these discourses.

2.1 | Conceptual tools of K–12 engineering education

In exploring teachers' pedagogical reasoning, one set of tools we focus on is key concepts in K–12 engineering education—the targeted objectives, design practices, curricular features, and learning outcomes articulated in K–12 engineering education policy and research documents (Crismond & Adams, 2012; Cunningham & Kelly, 2017; National Academies of Science, Engineering, and Medicine [NASEM], 2021; Next Generation Science Standards [NGSS] Lead States, 2013). These tools include frameworks detailing engineering design processes and strategies (Crismond & Adams, 2012), design problem-based learning (English & King, 2017), epistemic practices of engineering (Cunningham & Kelly, 2017), and/or disciplinary values, such as learning from failure (Johnson et al., 2021; Lottero-Perdue & Parry, 2017), human-centered design (Hynes & Swenson, 2013), and socio-ethical perspectives (Gunckel & Tolbert, 2018).

These conceptual tools have largely been developed and disseminated by the precollege engineering education community in the past two decades, in response to the need to address a "pipeline" problem in the engineering workforce (National Academies, 2007). Rather than exact replicas either of what professional engineers use or higher education engineering curriculum, these tools were designed to address the kinds of disciplinary literacies needed to recruit students into engineering and prepare them for sociotechnical problem-solving of the 21st century (American Society for Engineering Education [ASEE], 2020). We point out these details to acknowledge that these political interests and objectives necessarily shape the development of these conceptual tools. We also acknowledge that tools in engineering education are also shaped by the broader cultures of engineering characterized as exclusionary and marginalizing (e.g., McGee, 2021; Pawley, 2009; Slaton, 2010), which create another set of tensions in drawing on engineering education toward more meaningful and inclusive learning environments. While these tensions are not the focus of our analysis, we return to these ideas more in the discussion.

Notably, the conceptual tools of K–12 engineering education are different from those in science and other school subjects, which has motivated attention to teachers' learning and conceptions of engineering (Hsu et al., 2011; Sengupta-Irving & Mercado, 2017; Wang et al., 2011). Much of this research has focused on teachers' understanding of particular conceptual tools, but with less attention on how teachers draw on these tools within broader contexts of K–12 schooling and toward more equitable learning. For instance, while engineering education has amplified design-based problem-solving, teachers report that these opportunities can be limited to students labeled in gifted programs. Early findings from engineering's integration into K–12 schools found that teachers restricted learning opportunities

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(Nathan et al., 2010) or constrained (Schnittka, 2012) engineering learning opportunities based on students' institutional academic achievement. Therefore, while design-based problem-solving offers teachers a new tool to engage their students in meaningful engineering work, it is shaped by the broader sociohistorical and sociopolitical contexts of K–12 schools in the United States.

2.2 | Dominant discourses of K–12 schooling

To examine how teachers' reasoning in engineering education is shaped by the cultural and political contexts of school, we attend to how teachers draw on dominant discourses in K–12 schooling. Similar to Gee's (1999) notion of "big-D Discourses," we do not just mean discourses as specific language that people use when talking about teaching or learning, but also how that language references, legitimizes, or excludes socially and culturally constructed values, beliefs, and ways of thinking, being, and interacting in communities. Drawing on both particular language uses and cultural models, discourses shape how people construct meaning. For example, Gee (2004) unpacks how a middle school teacher responded to questions about racism and poverty in her city. This teacher's language reflected more than just her individual reasoning, but tapped into broader discourses of individual responsibility, including that one's problems stem centrally from one's behavior and correcting one's behavior and appearances is the primary remedy. This example illustrates how discourses shape meaning about the available roles (individual person who either demonstrates acceptable behavior or does not), how resources should be distributed (individuals who demonstrate accepted behavior receive greater resources), and what structures are needed in communities (programs focusing on individual's behaviors or appearances).

Dominant discourses are powerful tools impacting teachers' reasoning and practice. Dominant discourses are prevalent in educational contexts and shape the roles, narratives, and resource distributions available. Because these discourses represent common sense, taken-for-granted societal assumptions, they often tacitly underlie individual teacher's reasoning as well as community-level norms and practices. In Schnittka (2012), we see how discourses of ability hierarchy, in which students have been historically labeled, sorted, and offered differing learning opportunities according to narrow measurements of ability, shape a teacher's reasoning about who can participate in design-based problem-solving. Dominant discourses obscure opportunities for other forms of language, cultural models, available roles, and use of resources. While dominant discourses hold significant power in shaping educational contexts, teachers have creative agency to push back on these discourses and disrupt the powered assumptions and relations inherent in them. Ultimately, we recognize that these discourses represent ubiquitous, implicit tools often underlying teachers' reasoning.

In our work as teacher educators and researchers examining teachers' pedagogical reasoning in an engineering education certificate program, we noticed two dominant discourses that emerged in class discussions and interviews: discourse of ability hierarchy and discourse of individual blame. These discourses are entangled with other ideological discourses of race, class, language, and gender (Leonardo & Broderick, 2011; Philip, 2011) and can therefore serve as mechanisms for racism alongside gender- and class-oppression even when teachers' reasoning does not directly reference race. Therefore, we see these discourses as having direct implications for efforts in fostering equity and inclusion in engineering education.

2.2.1 | Discourse of ability hierarchy

Pervasive in K–12 educational system is the discourse of ability hierarchy, which depicts students as positioned in a set ranking based on their perceived academic abilities. In classrooms, faculty meetings, and informal conversations, this discourse integrates pervasive language ("bright" vs. "slow" or "top students" vs. "low group") (Horn, 2007; Louie, 2020) and cultural models that stereotype students into fixed levels of ability, positioning those at the top of the hierarchy as more deserving of material advantages (Leonardo & Broderick, 2011). While it can be productive for teachers to identify students' areas of strengths and weaknesses, we argue that discourses of ability hierarchy recruit teachers to sort and rank their students in a rigid continuum, which often fails to recognize the resources of students marginalized by race, gender, socioeconomic status, and other characteristics (Ford, 1998).

In this discourse, the teachers' role is to determine students' abilities, typically using narrow measures like standardized tests or performance assessments, and to compare and rank students based on these measures. Students are passive

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in this discourse, filling slots to comprise a hierarchy, so that some students are at the top, "high-achieving," and others at the bottom, "low-achieving." Even when teachers use descriptors such as "advanced" or "high group" without referencing a "low-achieving" group, Leonardo and Broderick (2011) emphasize how any measure of "smartness" requires its dialectical opposite to exist. The existence of any qualifier for smartness necessitates the legitimacy of its denigrated other, the non-smart. This discourse impacts the distribution of resources, such as who gets to participate in gifted and talented programs or open-ended project-based learning. It also shapes the pedagogical structures used in classrooms, including ability groupings or labels used to mark and stratify students (Cohen & Lotan, 1995; McDermott & Varenne, 1999). Notably, this discourse obscures how smartness is socially and politically constructed (Leonardo & Broderick, 2011). As Hayman (1998) points out: "we make some people smarter than others, by rewarding the smartness of some people and ignoring the smartness of others. We make some people smart, in short, just by choosing to call them that" (p. 26). While this discourse has been explored in engineering education at the university level (Dringenberg et al., 2022; Secules et al., 2018), the implications have been underexamined in K–12 engineering education.

Challenges to discourse of ability hierarchy emphasize the multiple competencies involved in disciplinary activities (Boaler, 2008; Moll et al., 1992) and how ability is not fixed but can grow with appropriate supports and opportunities for learning (Dweck, 2015). As opposed to positioning students along a linear continuum, disruptions to discourse of ability hierarchy might position students as bringing a multiplicity of strengths to disciplinary learning (Wilson-Lopez et al., 2016), while also recognizing the heterogeneity of learners' experiences and needs. Teachers may draw on language that recognizes the multiple ways students can contribute to disciplinary activities; rather than using hierarchical language, teachers might "assign competence" across all students (Cohen & Lotan, 1995). These counter-discourses emphasize the need to shift educational resources from ranking and sorting students along narrow measures to recognizing the diverse assets that students can bring to solving disciplinary problems.

2.2.2 | Discourse of blaming students

The discourse of blaming students is centrally about positioning individual students as primarily responsible for their circumstances, rather than considering how systemic conditions distribute resources and opportunities disparately across communities. In this discourse, language such as "students don't care," "students need grit," or "no excuses" attributes problems to students (and their home communities) (Philip, 2011) and tap into cultural models of individualism and deficit narratives, particularly for students from racially and economically marginalized communities (Ladson-Billings, 2007). Here, teachers' roles are to place the locus of responsibility for problems on students; students are then positioned antagonistically, in being the source of problems. This discourse impacts the distribution of resources to solve problems, motivating resources and structures focusing on "fixing students," rather than looking at the role of pedagogical and systemic structures in constructing problems (Gourlay & Deane, 2012).

This is not to suggest that every instance when a teacher assigns responsibility to individual students is problematic; as educators we know how important it is for students to recognize and take responsibility for aspects of problems within their control. However, in US educational contexts, the dominant discourse of blame centers on individual responsibility, often leading to students being held responsible for things outside of their control. This discourse forecloses opportunities to consider how educational problems can be attributed to structures of inequitable political and economic systems that provide unequal access to resources and distributions of labor. For instance, the educational problem of "incomplete homework" is often framed as solely the fault of a student, with individual consequences for their academic standing (Calarco et al., 2020). However, research has suggested that homework completion and efficacy is tied to students' socioeconomic status and geographic location (Bowd et al., 2021), pointing to the broader structural dimensions of this problem.

Challenges to discourses of individual blame therefore recognize how educational systems, as well as other societal, political, and economic structures, contribute to the construction of educational problems. Rather than "blaming students," teachers may instead foreground systemic issues producing these problems—or reframe what counts as an educational problem (Philip, 2011). For instance, in the homework example, instead of using language that "students aren't motivated," teachers' reasoning might acknowledge the unequal access to resources contributing to homework completion. Alternatively, they might deconstruct whether differential homework completion is a problem for their class. These counter-discourses shift resources toward consideration of pedagogical practices in relation to these systems and/or to addressing systemic issues.

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2.3 | Research questions

Dominant discourses shape K–12 schooling in the United States and are prevalent resources for teachers' reasoning about problems of practice. Yet little work has explored the relationships between these discourses and the disciplinary objectives, design practices, curricular features, and learning outcomes in engineering education. In this article, we ask:

1. How does teachers' pedagogical reasoning about engineering connect to dominant discourses of hierarchy and blame?
2. How does their reasoning draw on conceptual tools of engineering in relation to these discourses?

3 | DATA COLLECTION

3.1 | Study context

This study takes place in the Tufts University Teacher Engineering Education Program (TEEP), an online asynchronous graduate certificate program in engineering education for in-service teachers, STEM specialists, and other K–12 educators. TEEP educators take four graduate-level courses over an 18-month period. Program goals focus on engaging teachers in disciplinary engineering content while also supporting the development of responsive instructional practices for students' engineering (Tables 1 and 2).

3.2 | Researcher positionality

The authors are educators committed to supporting more equitable and inclusive forms of engineering in K–12 classrooms, yet bring different perspectives and experiences impacting our research interests, epistemology, and methodology (Secules et al., 2021). In our author team, we have former classroom teachers, who shaped our thinking

TABLE 1 Tufts University Teacher Engineering Education Program (TEEP) learning outcomes and sample activities for engineering content courses.

Learning outcomes	Sample topics and instructional activities
Understand engineering as a professional discipline	Read, analyze, and discuss resources about professional engineering: • IDEO shopping cart video (Koppel & Smith, 2006) • TedX—leveraged freedom wheelchair (Winter, 2012) • *The design of everyday things* (Norman, 2013) • *Engineering your future* (Oakes et al., 2004) • *Field guide to human centered design* (IDEO, 2015)
Engage with specific knowledge and skills in engineering	Participate in targeted lessons on key topics in engineering design: • Simple machines • Computational thinking and programming • Electricity and basic circuits • Statics (tension and compression) • Engineering design practices (decision matrices, design interviews, design documentation)
Develop understanding of, and facility with, design processes	Engage in solving ill-defined, complex design problems that are challenging for adult learners: • Automated mixer • Robotic fish feeder • New touch sensor for LEGO EV3 • Self-selected client design project

Note: TEEP learning outcomes for engineering content courses include understanding professional engineering, engaging in engineering knowledge and skills, and exploring the engineering design process. Instructional activities and topics are informed by professional engineering, higher education engineering disciplinary resources, and K–12 engineering education resources.

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TABLE 2 TEEP learning outcomes and sample activities for engineering pedagogy courses.

Learning outcomes	Sample instructional activities and topics
Understand and interpret research, theory, and practice resources related to engineering teaching and learning	Read, analyze and discuss data-rich publications and resources on teaching and learning engineering: • Informed Design Teaching and Learning Matrix (Crismond & Adams, 2012) • Reflective Decision-Making in Elementary Students' Engineering Design (Wendell et al., 2017) • Examining STEM integration in a HS course (Valtorta & Berland, 2015) • Responsive Teaching in Science (McKean et al., 2017) • *Talk Science Primer* (Michaels & O'Connor, 2012) • Synthesis Lectures by instructors on Failure, Planning, Clients' and Context
Cultivate responsive practices for attending to student thinking in engineering	Practice eliciting, noticing, and responding to students' engineering thinking: • Interview a student about an engineering mechanism (wind-up car, squirt gun, electric pencil sharpener) and write an analysis of the students' thinking • Analyze and discuss videos of students engaged in engineering activities • Collect and analyze video of students in your school doing engineering
Apply understandings of engineering and responsive teaching to lesson and unit planning	Evaluate and design activities with attention to different aspects of engineering and students' thinking: • Analyze and categorize existing engineering activities (e.g., TeachEngineering.org, Engineering is Elementary, Engineering the Future) • Develop short tasks and lessons related to particular aspects of engineering • Design and document an engineering activity in classrooms, including anticipations of student thinking and artifacts as well as structures for responsive teaching

Note: TEEP learning outcomes for engineering pedagogy courses include understanding theory, cultivating responsive practices, and applying understandings of responsive engineering teaching. Instructional activities and topics are informed by engineering education research, policy, and curricular resources.

around the broader institutional contexts in introducing engineering to classrooms. We are also university-based teacher educators, which attunes us to thinking about what it means to support teacher learning in both moment-to-moment interactions and in their developmental trajectories. We are all cis-women who participated in advanced formal learning in engineering and science; these experiences both elucidate—from our marginalized positions in these fields—and obscure—given our success in navigating these fields—how dominant discourses show up in engineering talk and practices, particularly in schools. Therefore, part of the analytic work in this article involved questioning what is taken-as-shared, opening for examination of the "settled" expectations for what is valued in schools and in engineering (Bang et al., 2012). This work influenced our methodological approach to consider broader contexts shaping the significance and interpretation of talk and social language (Fairclough, 2010; Gee, 2004). Lastly, as a Black woman first-generation student, the first author's particular racialized, gendered, and classed experiences in engineering focused our understandings on how the powered work of discourse manifests in distributions of resources.

We acknowledge that three of the four authors were involved in designing and instructing the program, bringing insider perspective to the data analysis. The first author was not involved in teaching in the program, which helped the team to question assumptions about teaching engineering and teacher learning and reframe our interpretations of teachers' interviews within broader contexts of teaching engineering (Maxwell, 2013).

3.3 | Participants

This study is a part of a broader project examining teacher learning in engineering education in TEEP. We recruited and consented 22 formal and informal educators enrolled in TEEP to participate in this research project. Not all TEEP educators were in the research project; those who consented participated in interviews, collected videos of students' engineering, and allowed us to analyze their coursework.

Our aim in this particular study was to understand how teachers took up engineering education conceptual tools within the context of K–12 schooling. We focus on a subset of 14 elementary educators and 1 high school teacher who focuses on science in a special education classroom. These educators are predominantly White female teachers ($n = 13$), with one White male teacher ($n = 1$) and one White nonbinary teacher ($n = 1$). This subsample included both novice and experienced teachers, ranging from 2 to 32 years of teaching experience. Given the online nature of the program, educators taught in diverse contexts; our sample included educators from six different states, in both public and private schools, and with a range of positions (e.g., gifted and talented teachers, STEM specialists, classroom teachers, librarians, and English language learner teachers).

3.4 | Data sources

The goal of the broader research project was to understand engineering teachers' noticing and responsiveness to students' engineering ideas. Data collection therefore focused on teachers' engagement with the coursework and their ongoing reflections on their developing engineering pedagogy. The high school teacher participated in one interview after the program, while the 14 full research participants were interviewed six times over the span of the TEEP (Figure 1). In the first semistructured interview, teachers were asked about their pedagogical goals for and prior experiences in teaching engineering, as well as their motivation for enrolling in the program. The next four interviews took place after each course, and teachers were asked about their course learning and how they had incorporated engineering in their classrooms. In the final interview, teachers reflected on their TEEP experiences and described changes they perceived in their teaching practice. In all six interviews, teachers watched and discussed videos of students' engineering activities. In Interviews 1, 4, and 6, these videos were from prior research projects; in Interviews 2, 3, and 5, teachers collected and discussed video from their teaching contexts. Additionally, we collected course artifacts such as teacher's posted responses to weekly reflection questions and submitted coursework.

4 | ANALYTIC METHODS

Our original goal in the broader research project was to examine shifts in teachers' pedagogical responsiveness in engineering during the program (Watkins et al., 2021). However, we found in our teaching and initial analyses that these shifts were often entangled with other aspects of teachers' pedagogical reasoning, such as when they positioned their students based on institutional labels of ability (ability hierarchy) or when they framed educational problems as solely the responsibility of individual students or families (individual blame). These noticings led us to develop a more expansive lens to teachers' reasoning. In an iterative process of theory-building and analysis, we delved into research on teacher ideologies and dominant discourses in K–12 education in the United States (e.g., Louie, 2017, 2020;

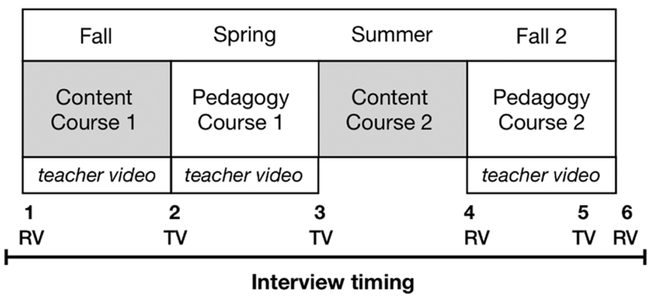

FIGURE 1 Timeline of TEEP courses and research data collection. Teachers collected video from their classrooms during Content Course 1 and Pedagogy Courses 1 and 2. Interviews 1 and 6 took place at the start and end of the program; Interviews 2–5 took place after each course. During Interviews 1, 4, and 6, teachers watched and discussed videos we had previously collected of students' engineering activities (Researcher Videos, RV), while during Interviews 2, 3, and 5, they watched videos collected from their own classroom (Teacher Videos, TV).

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Philip, 2011) as we read through teacher interviews. The first author read full transcripts from three teachers to explore intersections between the literature and teachers' reasoning. This led to our development of post hoc research questions focusing on how teachers drew on dominant discourses in reasoning about teaching engineering.

For this study, we analyzed teachers' pedagogical reasoning across their interviews. Our first phase of analysis began with the classroom teachers ($n = 8$), for which 47 interviews were recorded and transcribed to capture teachers' meaning (one teacher's first interview recording malfunctioned). We reduced this primary dataset to shorter segments of teacher talk using Horn's (2005) construct of episodes of pedagogical reasoning (EPR) to identify and bound moments when teachers describe issues in or raise questions about their teaching practice specific to engineering activities. To qualify as an EPR, teachers' talk had to include elaboration of reasons, explanations, or justifications surrounding the engineering-activity-related problem of practice. After all authors collaboratively segmented six transcripts (representing approximately 10% of this data corpus) to establish these criteria for identifying EPRs, the remaining transcripts were segmented by the first author.

This data reduction process was conducted in conjunction with iterative cycles of code development. This phase of analysis was informed by critical discourse analysis (Fairclough, 2010; Rogers, 2004) to understand how a teacher's use of language not only points to their meaning-making about teaching engineering, but how they are building "identities, relationships, and narratives of the social world" (p. 6, Rogers, 2004). Further, this language use has political implications for the distribution of resources like status, social goods, and power (Gee, 2004). Therefore, in analyzing EPRs, we looked for evidence of teachers' reasoning in relation to dominant discourses of ability hierarchy and individual blame by considering (1) the language features in teachers' talk, (2) how teachers' reasoning tapped into cultural models positioning teachers and students in particular roles, and (3) the implications of teachers' reasoning for the distribution of educational resources. Note that critical discourse analysis is not trying to infer or make claims about teachers' intentions, but is highlighting the function of the language and models in teachers' reasoning for broader systems of inequity.

Within the EPRs identified as having evidence of either of these two discourses, we developed exploratory themes to characterize how aspects of engineering interacted with these discourses. Each member of the research group independently identified these themes in EPRs in a subset of interviews. We then met to collaboratively discuss and refine our themes, relying on our different positionalities, expertise, and perspectives (Smagorinsky, 2008). For instance, we started with themes to characterize how EPRs reinforced or disrupted dominant discourse, based on the language they drew on, the roles their discourse made available to teachers and students, and what their reasoning implied for the distribution of resources. However, we found a subset of EPRs that did not cleanly fit in either theme because they drew on language and roles from ability hierarchy discourse, but by inverting the hierarchies their reasoning challenged inequitable distribution of resources. Therefore, we developed a new theme, retooling, to reflect these differences. Selecting a subset of two interviews each from five classroom teachers (10 interviews), the entire author team collaboratively discussed, developed, and refined the subcategories (reinforce, retool, and disrupt) in each discourse. The next set of interviews (37 interviews) was collaboratively discussed by a pair of researchers, bringing ambiguous examples to the research group for further theme refinement. For instance, we expanded retooling to not just include examples in which teachers' reasoning inverted hierarchies, but whenever they drew on language and roles from ability hierarchy to challenge inequitable distributions of resources or status. With these set themes, the final 37 interviews were characterized by a single researcher, who identified marginal cases to discuss with the group.

4.1 | Limitations

Although this analysis reveals important interactions between dominant discourses in K–12 education with concepts in engineering education, there are limitations in how it can reflect the full complexity and scope of these interactions. As this study was a secondary analysis, we would expect to get richer, more in-depth data with interviews and teacher conversations targeting these interactions. Further, given the online, asynchronous nature of the program and research, we had limited access into the contexts in which teachers were drawing on these tools and how they were implemented in their classroom and institutional practices. However, we see value in shedding light on these patterns as a launching point for more careful attention to how tools of engineering education are situated in broader discourses of K–12 schooling and how these interactions may continue to distribute resources in unequal ways.

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5 | FINDINGS

This section details (1) how dominant discourses of hierarchy and blame surfaced in teachers' pedagogical reasoning about engineering education and (2) how teachers drew on conceptual tools of engineering education in interaction with these dominant discourses. In Table 3, we summarize how these two dominant discourses manifested in teachers' reasoning.

5.1 | Discourse of ability hierarchy

In their pedagogical reasoning, participants drew on discourses of ability hierarchy when comparing students' engineering engagement to other academic subjects or to other groups of students. For instance, when reasoning about why some students had trouble generating design ideas or receiving feedback from peers, teachers often drew on language and cultural models that attribute differential patterns of engagement to fixed-ability-based groupings. The specific practices associated with engineering disciplinary activities were conceptual tools for teachers to reinforce or retool discourses of ability hierarchy. In reinforcing hierarchy discourses, teachers mapped established institutional status hierarchies (e.g., "high" and "low" achievers) to explain or justify students' achievement in particular engineering practices, resulting in inequitable distribution of resources. In retooling hierarchy discourses, teachers continued to use academic rankings, either by referencing labels established in traditional academic subjects (e.g., "higher students," "super smart kids," or "lower ability students") or by establishing new hierarchies (e.g., "my low students are better at engineering because it involves more creativity.") While retooling is similar to reinforcing discourses of ability hierarchy in preserving the need to rank and sort students, the difference lies in how teachers drew on these discourses to advocate for more equitable distribution of educational resources. We also found that participants drew on concepts of engineering education to disrupt the function of the hierarchy discourses. Here, teachers drew on concepts of engineering education that recognized students' variegated abilities as different assets for engineering learning, subverting the discourses centering homogenous learning outcomes to place students on a hierarchy.

TABLE 3 Summary of findings.

Description of dominant discourses evident in teachers' reasoning	Patterns in how conceptual tools of engineering education interacted with dominant discourses
Discourse of ability hierarchies: Positions students into fixed and stratified ability categories. Teachers' role is to rank and sort students. Discursive markers include language identifying students as "high"/"low" ability grouping Resources are mobilized to benefit those positioned at the top, often at the expense of those at the bottom (e.g., teachers' attention). In contrast, those positioned at the bottom are justified to be ineligible for educational resources (e.g., gifted and talented programs, STEM enrichment programs).	*Reinforce*: Drawing on features of engineering activity (e.g., engineering as open-ended and ill-defined) to reproduce ability hierarchies established in other academic contexts. *Retool*: Drawing on features of engineering activity (e.g., failure as inherent to the Engineering Design Process) to establish different ability hierarchies than in other academic contexts; some students positioned as struggling are now accomplished and vice versa. *Disrupt*: Drawing on features of engineering activity (e.g., emphasis of process over product within the Engineering Design Process) to challenge the legitimacy of ability hierarchies, expanding notions of competency.
Discourse of individual blame: Positions students as primarily responsible for their circumstances. Teachers' role is to attribute educational problems to students' deficits for circumstances outside of their locus of control. Discursive markers include language that points to an apparent student deficit and positions this deficit as responsible for unmet expectations. Resources are mobilized to correct an individual student's deficit rather than to address structural circumstances (e.g., punitive practices vs. system interventions).	*Reinforce*: Drawing on features of engineering activity (e.g., the role of drawing in the Engineering Design Process) to identify unmet expectations as the responsibility of students. *Disrupt*: Drawing on features of engineering activity (e.g., the role of drawing in the Engineering Design Process) to identify unmet expectations as the result of larger structural/systemic arrangements.

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5.1.1 | Reinforcing discourse of ability hierarchy

In this theme, participants drew on concepts of engineering education to reinforce discourses of ability hierarchy. Teachers used language referencing preexisting labels of students' competencies ("low-achieving," "higher students") and continued to position students in these rankings. These status-linked fixed-ability labels did not originate from the program, rather the language and meaning were tied to teachers' instructional contexts. As hierarchy discourse is pervasive in K–12 schooling in the United States, we observed that engineering concepts served as tools for setting up another set of narrow and homogenous standards to reinforce hierarchies of students' academic abilities established in other subject areas.

Jamie, a STEM specialist, discussed in her second interview the video she collected of students engaging in engineering outside of school. We observed that her reasoning about one student's work drew on the discourse of ability hierarchy:

> He's **incredibly smart**, so I don't know if then there's more of a challenge I could've given him? Because it almost seemed like it was too easy for him to tackle it … I would describe him as **gifted** and really just his **level of understanding**, what can I do with a student like that really does challenge him? So he has to think through it.
>
> (Jamie, Interview 2, emphasis added)

Jamie referenced fixed-ability language of "incredibly smart" and "gifted" to label this student at the top of an ability hierarchy. She positioned his "gifted" abilities as universal—his "level of understanding" as greater than other students. This positioning warranted him more explicit teacher attention; indeed, she spent more time discussing his engagement than the other students in the video.

When asked to expand what she meant when she described this student as "really smart," Jamie elaborated that when she taught him in prior years, she met with him one-on-one to provide additional opportunities for complex coding and design projects. She even included him in writing a grant for funds for a new classroom design challenge. This example highlights how reinforcing the discourse of ability hierarchy can impact what opportunities are provided to students, in this case, offering students at the top of the hierarchy more extensive teacher–student interactions and opportunities for agency and learning in engineering. The emphasis on problem-solving in engineering afforded possibilities for distributing additional resources and reinscribing this student's academic status.

We saw similar themes in an excerpt from Jocelyn's entrance interview where she shared an activity she led in her fifth-grade classroom that represented what she calls her "typical vision" of engineering. She described a project where students conducted research on skyscrapers, and then designed, calculated, and constructed a scale model. While these activities represent different engineering practices described in K–12 engineering frameworks (e.g., ASEE, 2020; NGSS, 2013), Jocelyn highlighted one practice that she thought only certain students could do—applying mathematics to build a scaled prototype.

> I had a **very gifted class** a couple years, it was probably two years ago—and so it was a class that I felt would be very able, math wise to do [this challenge]. Not every class, I think at fifth grade level, could try to build them to scale.
>
> (Jocelyn, Interview 1, emphasis added)

Drawing on engineering as a problem-solving activity that integrates mathematics (and science) to design solutions, Jocelyn discursively positioned her "gifted class" as more capable to "try to build" the skyscrapers to scale. As with the first example, this use of ability hierarchy discourse is more than just words—it impacted the distribution of educational resources: the students who were positioned at the top of the academic hierarchy were the ones who were given opportunities to try complex engineering projects.

We observed other instances in which teachers' reasoning drew on the idea that engineering is an application of math and science when reinforcing the discourse of ability hierarchy. For example, in Interview 2, Bryn, a gifted and talented elementary school teacher, discussed a video she collected of her class designing a circuit with a switch. She expressed surprise that a particular student had observed a rubber band conducting electricity in her circuit:

> That girl is a **pretty brilliant** student, so I was trying, I hope I effectively covered how shocked I was that she thought that a rubber band was a conductor.
>
> (Bryn, Interview 2, emphasis added)

As in the other examples, this teacher drew on language of fixed-ability hierarchy—"pretty brilliant student"—to make sense of her student's reasoning. She shared how she tried to hide her surprise at this student's mistake. Given that this teacher was positioned within a gifted and talented program in her school, it is perhaps not surprising that she would draw on perceived rankings of her students' academic abilities. Yet this example shows the potential peril not just to the students at the bottom of the apparent hierarchy, but also at the top. For students who are labeled "smart" or "brilliant," there is an expectation of getting the right answer, demonstrating the correct procedures or skills, and out-performing others. Deviating from this expectation risks losing the "high-achieving" designation, potentially foreclosing opportunities to explore one's thinking beyond correctness and learn from failure (Dweck, 2015).

Lastly, we saw that teachers drew on the discourse of ability hierarchy to grapple with the novelty of engineering in K–12 schooling. In her fifth interview, Denise, a librarian who teaches K–8 students STEM once per week, considered how to support students in understanding the design process:

> And I think the rest of the class were at a higher level or more comfortable with it and the process, I think it would be easier to either have **my high achieving students** work with people that are new.
>
> (Denise, Interview 5, emphasis added)

Denise's reasoning again drew on labels of ability hierarchy—"high achieving students"—to position some students as capable of helping other students in engineering. Drawing on this discourse sets up narrow roles for students to either be helping or receiving help from "higher" students, perpetuates academic status hierarchies, and limits the opportunities for all students to learn about heterogeneity in engineering.

Summary: In this theme, we found that teachers' pedagogical reasoning could reproduce dominant discourses of ability hierarchy by drawing on language that positions some students as inherently more academically capable than others. Their reasoning also drew on concepts in engineering education, for instance, that engineering design involves complex problem-solving, that engineering involves applying mathematics or science, and the novelty of engineering in K–12 schooling. The entanglement of ability hierarchy and engineering education concepts impacted the distribution of educational resources and status—who received opportunities to engage in complex projects, who could help others, and who was seen as successful.

5.1.2 | Retooling discourse of ability hierarchy

In this theme, we considered how teachers could continue to draw on discourses of ability hierarchy when reasoning about teaching engineering, but in ways that challenged inequitable distribution of resources or status. Teachers continued to draw on language of ability hierarchy ("gifted," "lower students"), at times referencing established ability labels from other school subjects. What makes this theme different from reinforcing, however, is that retooling hierarchy discourses describes instances in which teachers either (1) used the labels to argue for more equitable distribution of resources or (2) established new stratifications differing from hierarchical rankings established in other academic contexts.

We present another quote from Denise exemplifying how educators could continue to draw on discourse of ability hierarchy but argue for more equitable distribution of resources. Denise, an elementary school librarian who transformed her school library to include a makerspace and taught K–5 students weekly, reasoned about including more engineering activities in her programming given that her context was the only space for engineering in her school:

> I want to have these kind of opportunities open to a wide range of kids and see where it goes. I have **mixed ability levels**, I have non verbal autistic kids that I want to be able to engineer. And you have the **super smart kids** and you want to expose all of them to all of these opportunities and not just limit it to the nerdy computer-y boys doing these kinds of projects, make it wide open and more, I don't know, less new when they get to [middle school.]
>
> (Denise, Interview 5, emphasis added)

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Denise drew on similar labels as in the prior theme to characterize her students based on "mixed" ability levels. This labeling did not question the perceived ranking of students, instead continued to position some students at the top ("super smart"), thereby positioning others in lower positions in perceived academic ability. However, unlike the examples in the previous theme, in this quote Denise used these labels to advocate for more equitable opportunities for students to experience engineering design. In particular, she recognized the history of who has typically had opportunities to engage in these activities, wanting to challenge that only "computer-y boys" would get to do these projects. Therefore, instead of reinforcing, we see her reasoning as retooling the discourse of ability hierarchies. Her reasoning preserved academic rankings of students, but to argue for more equitable distributions of opportunities or resources.

We also characterized quotes as retooling when teachers established new stratifications differing from hierarchical rankings established in other academic contexts. For instance, Brad, who co-taught a third-grade inclusion classroom with a special education teacher, reasoned about how engineering projects could provide opportunities for his special education students to be the "wizards":

> ... My **higher functioning** students knew how to read but didn't know how they knew how to read. So when we gave them a problem of coding, they struggled because they couldn't figure out how to do that. Whereas my special ed students, who are still learning how to decode words and how to read, actually picked up on it ten times faster ... my special ed kids who are at **Kindergarten or first grade level** are going to go: 'no, you have to break it apart into this' ... **They're like the wizards** ....
>
> (Brad, Interview 1, emphasis added)

Brad made sense of his students' activities based on how the educational system has ranked them: "higher functioning" and "first grade level." However, in contrast to the examples of reinforcing hierarchical discourses, he drew on specific practices of coding and engineering—namely the need to break down problems into smaller pieces—to set up new stratifications in engineering. The students who have been positioned at the bottom of the academic hierarchy now fill the role of being at the top: "They're like the wizards." Therefore, the students who had been positioned with higher academic abilities in other subjects were now the ones at the bottom of the hierarchy in engineering; they are now the ones "failing." While this may seem like a positive reversal in that it redistributed higher educational status, we argue that his reasoning maintains the need for hierarchy in schools. Rather than recognize the heterogeneous resources that students can bring to engineering, Brad continued to rank and sort students as inherently more or less capable in engineering.

Teachers also drew on the hands-on nature of engineering or a focus on building with materials to invert hierarchies in their classroom, as seen in the following quote from Alma, an elementary STEM specialist teaching grades 3–5:

> There are my kids with all the book smarts. If I give them something hands-on to do, they struggle. My **lower end** kids, you know, they have a lot of trouble with the book knowledge, reading it sometimes and understanding it, but giving them the handson, I've never seen anything like it. It's like, I feel like they have a different intelligence ... I can't pinpoint what it is, but those **higher achieving** kids, they've got a lot of book smarts, they can do it, but they struggle with the hands-on. The **lower kids**, they can build anything you ask 'em to build. The **higher kids**, they cry. They almost break down, because they can't build it or they can't do it. The **lower kids**, they don't give up, they keep on. Do you understand what I'm saying? So I almost think it's a different type of intelligence, but I don't know what you would call it.
>
> (Alma, Interview 2, emphasis added)

Alma reasoned about the differences between her students' engagement in engineering design by using their academic rankings, for example, "higher achieving" and "lower end" kids. Like Brad, she drew on particular practices of engineering—building, working with materials to realize ideas, learning from failure—to flip the hierarchy established in traditional academic subjects. The "lower" students are positioned as successful at building, working with their hands, and persevering through challenges, while the "higher" students are positioned as less successful on tasks that do not require "book smarts." Again, we see that this reversal of fortunes can disrupt the inequitable distribution of educational status, but by preserving the need to rank students inherent in the dominant discourse of ability hierarchy, this disruption is limited both for who students can be in engineering as well as for understandings of engineering as a heterogeneous activity that can draw on students' diverse resources and experiences (Wilson-Lopez et al., 2016).

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Summary: Across this theme of retooling discourses of academic hierarchy, we found that the novelty of engineering in schools and unique practices of engineering design—namely building prototypes, working with materials, breaking down problems into smaller parts—afforded opportunities for teachers to reason about more equitable distribution of status and educational opportunities for their students. However, we also observed that this reasoning preserved the need to assign rankings to students for their perceived academic abilities. Therefore, while retooling discourses of academic hierarchy can offer disruptions to traditional narratives about who is deserving of engineering opportunities and who is seen as successful, there are limitations to how retooling can challenge systems and structures that stratify students.

5.1.3 | Disrupting discourse of ability hierarchy

The last theme reflected how participants drew on engineering concepts in ways that disrupted discourses of ability hierarchy, challenging the legitimacy and necessity of ranking students in fixed positions of ability. In this theme, elementary engineering teachers drew on heterogeneity in engineering practice to value the different talents and capacities of all their students, without drawing on established hierarchies or setting up new ones.

In her fourth interview, Janet, a third-grade classroom teacher, reflected on her own experiences doing engineering to reason about how engineering can offer opportunities to value students' strengths:

> [Teaching engineering in schools] also recognizes the fact that so many kids have **different skill sets** that if you approach the brainstorming with the concept that brainstorming isn't just making a web, it can be reading, interviewing, making a call. It hit a lot of the different- A kid who's artistic might do the collage whereas me, I always write …. So it's nice as an educator to see that **engineering can bring in that flexibility of students' strengths** because it's not just documenting and drawing, you can make it so much more if that makes sense.
>
> (Janet, Interview 4, emphasis added)

In this quote, Janet drew on the heterogeneous skills needed in engineering—reading, writing, interviewing, drawing, and making a collage—to reason about how engineering can draw on different students' strengths. Rather than using traditional academic hierarchies or even developing new hierarchies in engineering, Janet's reasoning foregrounded the idea that students bring different skill sets that can be utilized and valued in classroom teaching. This disruption of academic hierarchical discourse can impact the distribution of educational resources using engineering activities as ways to undermine status hierarchies and assign competence across learners (Cohen & Lotan, 1995).

In her final interview, Margaret, a third-grade teacher, talked about how including more engineering activities had impacted her classroom culture. She highlighted the ways failure and iteration, alongside heterogeneity in engineering, shaped who is seen as successful:

> … it's inherent in the engineering design process, with solution diversity, and testing, and iterating, and that **there's not an expectation that you're going to get it right the first time. There's almost an expectation that you're not going to get it right the first time,** or the second, or the third … They're finding, not just using their words, but using drawings to express themselves better, making a more careful drawing, and realizing that they can make what I used to call like a technical drawing, you know, **God gives everybody their different talents. We're not expecting everyone here to be the greatest artist ever**. Can you make your idea clear through a drawing, a careful drawing, a labeled drawing?
>
> (Margaret, Interview 6, emphasis added)

Margaret drew on the emphasis on failure and iteration in the engineering design process to reason about her expectations for her students' engineering activities. Rather than positioning students as having fixed, ranked abilities, Margaret positioned her students as continually learning from their design failures, not expecting them to "get it right the first time." Margaret's reasoning also drew on the heterogeneity in engineering, both in solution diversity and the heterogeneous skills and practices in engineering design. This heterogeneity offered ways for students "different talents" to be valued in the classroom. Rather than drawing on engineering practices to set up new hierarchies based on

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these talents, she considered how engineering practices can support students in service of larger educational objectives, for instance, to learn about how technical drawings can be used to communicate their ideas.

Summary: In disrupting discourse of ability hierarchy, we found instances in which teachers made sense of their students' different performances in engineering not in terms of their hierarchical academic labels, but how engineering afforded opportunities to showcase students' different strengths and talents. In this theme, we found that teachers' reasoning largely drew on the heterogeneity in engineering, including the ways diverse solutions, design perspectives, and skills are needed for complex, ill-defined engineering problems. These disruptions offered opportunities for all students to engage in complex problem-solving and for more students to be positioned as valuable academic contributors.

5.2 | Discourse of individual blame

We also observed that participants could draw on engineering conceptual tools in interaction with discourses of individual blame. Tapping into discourses of individual blame occurred when teachers were sensemaking about moments when students' engineering work did not align with their conceptions of what engineering should look like. In some contexts, we saw teachers reinforce discourses of individual blame, when aspects of engineering practices, such as sketching prototypes, accepting peer feedback, and persisting through design failures, served as conceptual tools to assign responsibility for problems solely to students. Unlike the discourse of ability hierarchy, our analyses of teachers' reasoning of individual blame did not produce examples of retooling. However, we did observe that engineering teachers' reasoning could disrupt discourses of individual blame, in which there was consideration of different pedagogical moves or approaches that contributed to educational problems. In a few instances, teachers also drew on tools from engineering education—namely the idea that engineering design has not been a traditional part of K–12 schooling—to point to the role of broader systems or structures.

5.2.1 | Reinforcing discourses of individual blame

In this theme, participants drew on concepts of engineering education in ways that reinforced discourses of individual blame. In their reasoning, teachers used language positioning students as primarily or solely responsible for educational problems, such as not meeting expectations around an aspect of engineering practice. This attribution was limiting for teachers' reasoning by focusing on students' deficits rather than the ways teachers' pedagogical moves could better support students or how systemic issues are at play in constructing an educational problem. For instance, Maya, a fourth-grade teacher, attributed blame primarily to her students for not meeting expectations for the socio-emotional skills needed in engineering:

> I feel like a lot of [engineering skills] are emotional skills as opposed to physical skills … **Collaboration and teamwork is another one. That doesn't come easily to my demographic, per se**. I think a lot of kids, especially in recent years have … they don't always love working as a team. But again, that might be my demographic. I've been working with these higher level thinkers for like five years now. **In either fourth or sixth grade, they don't love working with others because they want to do it right the first time and they know they can do it by themselves**.
>
> (Maya, Interview 6, emphasis added)

Drawing on the emphasis in engineering on collaboration, Maya's reasoning positioned students as centrally responsible for the problem of not easily working together as a team. Making the students the focus of the problem, Maya reasoned about why her students might struggle in this aspect of engineering—these students do not want to work with others because they want to complete the task individually and efficiently (also drawing on ability hierarchy discourse in her reasoning). Rather than attending to how the educational system has prioritized individual achievement (particularly for "higher level" learners) and given higher status to students who complete tasks quickly (particularly in STEM subjects), the teacher's focus was on fixing the students' deficits. Attending to these systemic issues could direct resources toward disrupting cultural norms of individualism and efficiency in schooling so that the environment is more conducive for students' collaboration.

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Jamie, a STEM specialist, also drew on discourse of individual blame when making sense of her students' lack of enthusiasm with learning about the Mars Rover:

> **These kids today, I feel like they, sometimes they don't grasp it**. Today we were watching the Mars Lander, the live stream, and I was trying to explain to them … I showed them some videos and I'm like, "Guys, this is pretty cool. Landing on Mars and all this stuff." And they're just kind of like, "Eh." **Very little impresses them … it's hard to, I think, fully engage them in a lot of what I think is really exciting** because I could give them worksheets and textbook stuff all day long.
>
> (Jamie, Interview 5, emphasis added)

Jamie linked the students' lack of engagement in watching and learning about the landing of the Mars Rover to their not "grasp[ing]" the wonder of the engineering work involved. Her reasoning attributed blame to "kids today," when they violated her expectations that they should be impressed by the ingenuity of engineering designs. By positioning the students in need of remediation, her reasoning missed opportunities to reflect on what engineering problems or solutions might be culturally relevant or sustaining to her students in their communities or to consider the ways in which systems and structures of K–12 education (e.g., standardized tests or scripted curriculum) have limited how schools can tap into students' interests.

Summary: Within this theme, we saw teachers' reasoning reinforcing discourse of individual blame by drawing on particular concepts and practices from engineering education, such as the emphasis on collaboration, the idea that engineering is an application of knowledge from mathematics and science, and the expectation that engineering designs should be inherently compelling and universally relevant for students. Teachers' reasoning in this theme placed overwhelming responsibility on students for not meeting expectations in these concepts and practices, limiting how teachers could consider the role that pedagogy, school culture, or broader systemic issues could play in constructing these problems.

5.2.2 | Disrupting discourses of individual blame

We also observed instances in which teachers' reasoning disrupted the discourse of individual blame, going beyond a focus just on students in scoping educational problems. One kind of disruption involved teachers foregrounding their pedagogy. For instance, in reasoning about a video from her students' classroom, Marlene, a third-grade science teacher, reflected on her role in supporting whole-class discussions in engineering, a common site for problems of practice.

> So it's a constant in this or anything that you're doing as a teacher. Is every voice being heard? Are the voices wanting to be heard? And then are their voices not being heard because they don't understand or their voices not being heard because their classmates are … And so for those kids that verbal isn't their thing. **What am I doing in my own teaching factors that is enabling those students to participate and share?** And then I think in terms of the engineering discussion, these guys came up with this whole theory about glue that I had never thought of, right? So they're like, "Glue is like cement" or, "Glue is rubbery" and I'm like, all right, it's hot glue. And then I got nervous, I can remember, I was like, I don't know whether this is really going to go and I didn't want to spend 45 minutes talking about glue. But … I feel like it captured the key concept, right?
>
> (Marlene, Interview 2, emphasis added)

In her reflection, Marlene considered two entangled educational dilemmas: how to support students to share their thinking and how to ensure that classroom discussions are productive for students' learning. At the same time, she acknowledged that engineering design should support students to exercise their agency to have their own ideas about form and function. Rather than blaming students for not participating in discussions or going off track, her reasoning foregrounded her pedagogical role in making space for students to share their thinking, even when she did not know where the discussion might go. While her reasoning acknowledged that some students might not be inclined to verbally share, it also emphasized how she as a teacher could foster an environment to enable their participation.

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We saw a similar disruption to discourse of individual blame in Alma's second interview. When describing how her students struggled with making a car wheel move on an axle, Alma considered what pedagogical moves she could have made:

> I'd like to see them having more of a discussion doing that rather than me going around and telling them, if you tape it, it's going to slide. **That should have been—that's what I'm saying, that should have been me laying down the criteria and the constraints a little bit better. And then we wouldn't have had a lot of that**. That would have been, probably more talking.
>
> (Alma, Interview 2, emphasis added)

Rather than attributing difficulties in figuring how to make an axle solely on the students' understandings, Alma drew on aspects of the engineering design process to consider how she could have better supported her students to grapple with how to make car wheels move. In her reasoning, the engineering education concepts of criteria and constraints were tools for her to reflect on her teaching to consider what supports she could put in place for her students' learning. Her reasoning therefore shifted educational resources not solely on remediating students, but on her engineering pedagogy.

There were fewer examples in which teachers reasoned about the role of broader systemic issues when attributing blame. The examples we did observe drew on the scarcity of engineering in K–12 schooling to reframe challenges as systemic issues. For instance, Jolene, a high school special education teacher, reasoned in a class discussion post: "*The reason I have such high rates of failure is due to these students not being exposed to engineering prior to my class*." Rather than placing blame on her students or her pedagogy, she considered how schooling had not provided sufficient opportunities for students to learn engineering and be successful in these challenges. Similarly, Janet drew on the novelty of engineering in schools to reframe her students' emotional challenges in engineering as a systemic issue. In her fifth interview, she described that at the start of the school year, her inclusion classroom students struggled emotionally with the difficulties of engineering tasks—crying, stomping, and trying to run out of the room. As she reflected on their growth in her classroom, she considered how having fewer opportunities earlier in their school career could have mitigated these challenges: "*I wish [the inclusion class] had gotten what they're getting from me sooner because maybe the beginning of the year wouldn't have been as hard*."

Summary: In our analysis, we found that teachers' reasoning could disrupt the discourse of individual blame. These disruptions occurred when teachers foregrounded their pedagogy in supporting students engineering, drawing on the engineering design process as a pedagogical scaffold or the importance of student agency in design. We also found that teachers' reasoning could reference the systems and structures playing a role in educational problems of practice, particularly by drawing on the novelty of engineering design in K–12 schooling. While these references were often tacit, as we unpack more in the discussion, we believe that acknowledging the lack of previous engineering opportunities is an important beginning for broader disruptions to the discourse of individual blame.

6 | DISCUSSION

6.1 | Research question 1: How does teachers' reasoning connect to dominant discourses?

Our findings showed that teachers' pedagogical reasoning could reinforce ability hierarchies and individual blame. The examples we presented may seem that they reflect "commonsense" or "natural" pedagogical reasoning—which speaks to the ways ideological discourses reflect taken-for-granted assumptions and relationships in K–12 schooling culture (Fairclough, 2010; Gee, 2004). For instance, it might seem natural to attribute blame to students for not meeting expectations about collaboration on engineering projects (Section 5.2.1—Maya, Interview 6), yet research asking Black students about their experiences collaborating in engineering points to how the broader sociopolitical contexts of K–12 schooling shape their participation (Wright et al., 2018). It might also seem ordinary that students who have been labeled as "gifted" should receive unique opportunities to participate in complex, challenging design tasks (e.g., Section 5.1.1—building a prototype skyscraper to scale from Jocelyn, Interview 1), yet research shows us that, regardless of their assigned ability level, students obtain higher levels of performance when they are placed in higher ability groups, due to increased access to rigorous and challenging material (Hallinan, 2003). Said another way, all students could benefit from complex and multifaceted engineering tasks. Challenging these seemingly common sense

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assumptions and relationships involves taking careful stock of how our language can (even unintentionally) perpetuate cultural models underlying inequitable distributions of resources.

Even when teachers seemed to be challenging inequitable distributions of status and resources, as perhaps Brad was seeking to do in labeling a group of students as the "wizards," their reasoning continued to draw on labels and roles that positioned students in hierarchies of ability (Section 5.1.2—Brad, Interview 1). We labeled this theme as retooling to recognize that continuing to draw on the same tools will not dismantle the need to set up educational environments requiring winners and losers, justifying competition for status and resources. When teachers' reasoning repositioned students who have typically been at the bottom of an academic hierarchy to the top, it failed to challenge the narrative that there must be those who can achieve in STEM disciplinary activities and those who cannot. This finding corroborates work from Sengupta-Irving and Mercado (2017), showing robustness in this pattern of teacher reasoning in engineering education.

Importantly, we saw opportunities where teachers' drawing on engineering educational concepts started to challenge dominant discourses of K–12 schooling, showing promising beginnings for how teachers might disrupt entrenched logics that iteratively justify ability hierarchies or individual blame for educational problems. These disruptions could involve reflecting on their pedagogy, identifying places where they might make different pedagogical decisions rather than positioning the students as solely responsible for a problem of practice. We consider the examples in our data as disruptive beginnings because teachers' reasoning rarely included explicit challenges to dominant discourses of schooling. However, we argue that these disruptive beginnings began to challenge what is taken as ordinary and expected in educational discourse (Lemke, 2002).

6.2 | Research question 2: How does their reasoning draw on conceptual tools of engineering in relation to these discourses?

Our findings also tease out how conceptual tools in engineering related to dominant discourses in teachers' pedagogical reasoning. Looking across the themes, we note that several examples of teachers' reasoning that reinforced or retooled dominant discourses emphasized narrow knowledge or skills in engineering education. For instance, when focusing on the role of math or science in engineering, we saw teachers' reasoning reinforce discourse of ability hierarchy to anticipate who could succeed in complex engineering tasks (Section 5.1.1—Jocelyn, Interview 1) or reinforce individual blame to consider why students did not meet particular expectations (Section 5.1.1—Bryn, Interview 2). In examples of retooling academic hierarchies, we observed that teachers' reasoning also focused on narrow skills or abilities, but those that are not typically afforded status in schools, such as Alma's emphasis on building (Section 5.1.2—Interview 2) or Brad's focus on the importance of breaking down problems (Section 5.1.2—Interview 1). In contrast, examples showing disruptions to these discourses tapped into the heterogeneity in engineering practice (Section 5.2.2—Marlene Interview 2 and Alma Interview 2), recognizing the diverse ways students can contribute to engineering (Gravel et al., 2021; Holly, 2021; Martin & Wendell, 2021).

Our examples also suggest how the design process can be used as a tool for pedagogical reflection. We argue that Alma took a "design-oriented" approach to make sense of her students' difficulties in creating an axle; she framed this pedagogical problem by considering what constraints she needed to introduce so that students were set up to succeed on this task (Section 5.2.2—Alma, Interview 2). In this way, we observed that teachers could take a design-based perspective to their teaching, making sense of students' engagement not just in terms of their individual attributes, but the classroom conditions in which students are engaging in engineering.

Another tool that appeared across our themes was the idea that "engineering is new in K–12 schools," which we see connected to the narrative in K–12 engineering education that the novelty of the discipline provides opportunities to shape how it is taught in schools, providing a clean slate for more equitable and engaging practices (Cunningham & Kelly, 2022). Yet our findings highlight that this same idea can be used to justify why only certain ("high-achieving") students can participate in complex engineering tasks (e.g., supporting new students, as in Section 5.1.1—Denise, Interview 5), showing that the slate is never blank, but carries the histories of the discourses and systems that will shape the implementation of engineering. At the same time, there were ways that the novelty of engineering in schools served to disrupt dominant discourses in teachers' reasoning, namely, to point to the role of the educational system in providing limited opportunities for students to experience and learn engineering early on in their schooling (Section 5.2.2—Jolene's Discussion Post).

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7 | IMPLICATIONS

This section discusses specific implications for teaching, policy, and education research that should be considered when reexamining the sociohistorical context of engineering and schooling in K–12 classroom learning.

7.1 | Implications for teaching

Our findings emphasize that we cannot teach engineering in a vacuum. Engineering teacher learning needs to go beyond supporting teachers' disciplinary understandings or even their deployment of ambitious pedagogical practices—it requires engaging teachers in deep pedagogical reasoning about the often taken-for-granted assumptions about schooling and the role that engineering can play in challenging or reinstating those assumptions. Often teachers' professional learning opportunities centered on educational equity are considered separate from the disciplines (King & Butler, 2015). This article adds to a growing body of work emphasizing the need for educators to consider discipline-specific perspectives in disrupting oppressive educational practices, systems, and structures (Gutiérrez, 2013; Larkin, 2019; Patterson & Gray, 2019; Wright et al., 2020). For instance, the finding that teachers can retool discourses of hierarchy using engineering-specific skills suggests the need to reflect on how to disrupt status rankings without setting up new winners and losers.

Rather than proposing a particular activity to address this aspect of teacher learning, we suggest looking for opportunities to engage with dominant discourses within existing activities. For instance, one common approach to support teacher learning is for teachers to engage in and reflect on their own disciplinary activities—which could serve as launching points for conversations about how to challenge narrow conceptions of ability in school (Watkins, 2023). Another common teacher learning activity is to use classroom videos to notice, interpret, and discuss how to respond to student thinking—teacher educators could find opportunities to consider how race, class, and gender intersect with their noticings of disciplinary thinking (Shah & Coles, 2020; van Es et al., 2017). Lastly, instead of focusing only on activities that target teachers as individuals with beliefs, understandings, and pedagogical practices, teacher educators could include local and broader contexts of school, for instance, by partnering with teachers to identify systemic leverage points (e.g., Chen et al., 2021) for promoting equitable engineering learning.

7.2 | Implications for K–12 engineering policy and research

Where some recent engineering education policy documents continue to identify learning engineering content as the primary path to educational equity (ASEE, 2020), we see significant promise in other engineering education policy documents that draw on asset-based perspectives—shifting away from hierarchical stratifications of ability to view students' capacities in multidimensional ways (Gravel et al., 2021). Although the goal of "engineering for all" seems inclusive, our findings suggest that policy and curricular documents that clarify the mechanisms of educational disparities in K–12 engineering education offer educators more effective tools for addressing educational inequity. Contributors to the recent consensus report, *Science and Engineering in Preschool Through Elementary Grades* (NASEM, 2021), do this by highlighting the institutional structures that support and constrain multidimensional forms of engineering learning. Rather than treating engineering learning as increasing isolated proficiencies in engineering skills or habits of mind, our findings suggest multidimensional framings of engineering—emphasizing the heterogeneity of skills and expertise necessary within the discipline—can support teachers' attunement to what students bring to the table.

Building on a thread of unpacking strength-based approaches in K–12 engineering education (Martin & Wendell, 2021) and calling for provocations to surface criticality in the field (Holly, 2023), our findings suggest increased theoretical attention to power and history in our educational research. Examples from other STEM disciplines can offer tools to understand how disciplinary concepts are entangled with inequitable cultures of schooling and how we can resist the reification of educational inequities in engineering education. For example, Louie et al. (2021) addresses the history of deficit discourses in mathematics teaching, proposing the framing–attending–interpreting–responding (FAIR) framework for enacting anti-deficit noticing in mathematics teaching—challenging deficit discourses about students and their communities. This framework addresses the entrenched inequalities of teachers' historic role in mathematics classrooms (deficit-oriented noticing) by highlighting existing practices of mathematics teacher noticing that can be leveraged in anti-oppressive ways. As momentum builds for engineering to enter K–12 classrooms, it is necessary to develop frameworks that can guide empirical investigations to recognize and understand example disruptions to these sedimented systems of inequality.

That discourses of ability hierarchy and individual blame surfaced in K–12 teachers' pedagogical reasoning about engineering suggests a need for more substantive theoretical connections to research on engineering culture at the undergraduate and professional levels, which locates these discourses as central to the exclusionary practices of engineering culture (Cech, 2013, 2014; McGee, 2016, 2021). Like this literature, we must foreground how discourses of individual blame and ability hierarchy are not race-neutral but are linked to the broader histories of Black and Brown students being positioned along a racialized hierarchy of ability (Martin, 2009) and their communities positioned as solely responsible for problems often out of their control (Philip, 2011). These scholars name meritocracy, in which success is attributed solely to individual attributes without consideration of contextual, structural, and systemic influences, as a core value of American professional engineering (Cech, 2013; Seron et al., 2018). Meritocracy naturalizes a narrow definition of ability, which constructs some engineering students—often racial, linguistic, and gender-minoritized students—as responsible for their failures (Secules et al., 2018). Research unpacking mechanisms of meritocracy within engineering in schools can articulate how broader engineering culture shapes the terrain of K-12 engineering education.

8 | CONCLUSION

Our findings reveal a complicated picture of engineering's integration into classroom learning, where educators, researchers, and policymakers invested in K–12 engineering must seriously contend with how educational inequities continue to manifest in schools. The material implications of teachers' engineering pedagogical reasoning reinforcing, retooling, or disrupting dominant discourses clarify the stakes of our work; if left unaddressed, engineering's integration into K–12 classrooms can reinscribe uneven educational opportunities even further. Ultimately, K–12 engineering education must heed this call to situate engineering disciplinary concepts in the inequitable histories of engineering and schooling cultures to understand more equitable learning possibilities.

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