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“That is Still STEM”: Appropriating the Engineering Design Process to Challenge Dominant Narratives of Engineering and STEM

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ABSTRACT

Teachers can play critical roles in challenging or reinscribing dominant narratives about what counts as STEM, who is seen within STEM disciplines, and how these disciplines should be taught. However, teachers have often experienced STEM in limited ways in their own education and are thereby provided with few resources for re-imagining these disciplines. While teacher educators have designed learning environments that engage teachers in new forms of disciplinary activities, there have been few accounts that describe how teachers make connections between these experiences and dominant narratives that impact their own and their students’ learning. In this study, I report on the experiences of Alma, a white, working-class, female elementary teacher in an online graduate certificate program for K-12 engineering educators. Through her engagement in engineering design in the program, Alma appropriated—transformed and made her own—discourse of the engineering design process in ways that trouble some of the narratives that restrict her, her family, and her students in STEM and in school. Alma’s experiences emphasize the need to consider not just what teachers learn about disciplinary tools and discourses, but how they transform these for their own purposes and contexts.

Introduction

There have been increasing calls to expand what STEM—science, technology, engineering, and mathematics—is in K-12 classrooms, challenging narrow visions of who is seen as competent, what counts as disciplinary, what experiences students should have, and what roles they can play (Bang et al., 2012; Calabrese Barton et al., 2013; Nasir et al., 2008; Philip et al., 2018). Sociohistorical narratives of what it means to learn STEM in schools portray it as a process of obtaining knowledge others have produced and applying formulas to others’ problems (Traweek, 1988). These narratives also position STEM disciplines as intellectual, academic work for the elite few who demonstrate mastery of limited practices (Bucciarelli, 1994; O’Connor et al., 2015; Traweek, 1988). For instance, in engineering education, the contributions of domestic domains, agricultural work, manufacturing, and other applied design trades have often been devalued as “less-skilled” labor with material consequences for pay and status (Frehill, 2004; O’Connor, 2003; Oldenziel, 1999), highlighting how class, race, and gender are intertwined in narratives of who and what counts as STEM.

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Teachers can play a role in perpetuating or, hopefully, challenging dominant narratives (Gay, 2010; Ladson-Billings, 1995). They can do this through the stories they (re)tell about how knowledge in STEM is produced and the images they depict of who are scientists, engineers, and mathematicians (Traweek, 1988). Teachers also have opportunities to disrupt (or reinscribe) dominant narratives through their interactions with school community members (other teachers, students, administrators, etc.) as they negotiate what counts as learning STEM in classrooms (Horn, 2007; Louie, 2020). Furthermore, teachers can provide opportunities to enact dominant narratives or construct new ones through norms and practices in their classrooms, particularly in how they position students and the discipline in their teaching (Leyva et al., 2021; Nasir & Hand, 2008).

However, K-12 teachers, particularly elementary teachers, have often experienced STEM learning in limited ways in their own schooling. Given the prevalence of lectures, initiation-response-evaluation discourse patterns, and labs that prescribe students' actions through step-by-step procedures in undergraduate classrooms, teachers' STEM preparation typically offers few resources for re-imagining these disciplines in K-12 schooling. To provide opportunities for teachers to experience STEM disciplines in more enriching and expansive learning environments, teacher education programs have engaged teachers in more meaningful forms of disciplinary activities (Hutchison & Hammer, 2010; Jaber et al., 2018; Rosebery et al., 2016; Wendell et al., 2019; Windschitl & Thompson, 2006). While these experiences have been shown to support teachers' disciplinary understandings and identities (Varelas et al., 2005; Windschitl, 2003), other work points to the need to understand how teachers' learning and participation in these spaces interacts with broader narratives that shape their experiences in these contexts and in schools (Varelas et al., 2005; Wright et al., 2020).

To address this need, I seek to learn from one elementary teacher, Alma (pseudonym), who made meaningful connections between her engagement in disciplinary activities during her professional learning in an engineering education program and dominant narratives about STEM in and out of school.¹ A first-generation college graduate, Alma's personal history had been shaped by dominant narratives about what counts as engineering. For instance, her family's work in textile mills, alongside other gendered, classed, and racialized trade work, has not typically been classified as engineering. This exclusion reflects the success of how professionals, academics, and policy makers narrowed boundaries of engineering and technology at the turn of the 20th century, positioning these disciplines as the work of the white, male, and upper class (Frehill, 2004; Oldenziel, 1999). Further, as a mother to a son who built their garage but whose abilities to plan, design, calculate, and build are not often recognized in schools, Alma has had to engage with narrow narratives of ability in STEM (Slaton, 2013). Professionally, her teaching in a mid-high poverty school has been necessarily shaped by sociohistorical narratives of control around what is to be taught and how teachers and students are to participate in learning (D'Amico Pawlewicz, 2020). In sum, while these narratives have impacted Alma personally, they also broadly restrict what is and who is seen in STEM, leading to persistent inequities in access, participation, and well-being in disciplinary learning spaces (McGee, 2020; National Science Foundation & National Center for Science and Engineering Statistics, 2019; Riley, 2008).

Through her participation in an 18-month online graduate certificate program in engineering education, Alma developed conceptual tools—understandings of what it means to learn a discipline and who belongs—that allowed her to navigate and challenge these narratives. I examined Alma's participation and discourse as she engaged in doing engineering by using LEGO robotics to solve design problems and as she reflected on her disciplinary learning and pedagogy. In my analysis of her online engineering laboratory assignments, course discussion posts, and interviews

¹While Alma's case is situated in an engineering education professional learning program, she makes links between her engineering learning and how "STEM" is taught in schools. In the paper, I draw on the STEM acronym to acknowledge its broader cultural and political significance in schools (indeed, Alma is a STEM specialist in her school), but specify in the analysis when Alma is drawing on engineering specifically versus referencing STEM generally.

throughout the program, I connected the shifts in Alma's participation in the engineering design process (EDP) to how she transformed and makes her own—that is, how she *appropriated* (Bakhtin, 1981; Levrini et al., 2015; Polman, 2006; Wertsch, 1998)—the EDP as a conceptual tool to trouble some of the sociohistorical narratives about STEM teaching and learning that have restricted her, her family, and her students. Framing my analysis, I asked the following questions:

1. What conceptual tools in engineering design discourse did Alma appropriate over the course of an online graduate certificate program?
2. How did Alma draw on these tools in ways that disrupt or challenge sociohistorical narratives about engineering, STEM, and school?

I highlight three potential contributions of this study. While others have argued for a shift in perspective from learning *of* disciplinary practices and epistemologies to learning *for* engaging in disciplinary work (Russ, 2014; Wendell et al., 2019), this study emphasizes the need to consider how teachers engage in disciplinary work to learn *to navigate and trouble* restrictive disciplinary narratives. In this view, teacher educators need to consider not just how teachers learn how to engage with disciplinary tools and discourses, but how they transform these for their own purposes and contexts. Building on theoretical advancements about appropriation (Levrini et al., 2015) to connect teachers' engagement in disciplinary activities and their navigation of sociohistorical narratives, this study highlights the multi-leveled nature of the resources and mechanisms involved in how teachers make sense of themselves and their students in STEM disciplines (Gresalfi & Hand, 2019). Lastly, this study connects to broader efforts supporting teachers to become more critical educators to challenge the inequitable structures limiting students in K-12 schools (Bartolomé, 1994; Carter Andrews et al., 2019; Gay & Kirkland, 2003; Kumashiro, 2004). While many of these efforts have been centered in social foundations courses, this work considers the needs and possibilities for discipline-focused teacher education courses (Mensah & Jackson, 2018; Morales-Doyle et al., 2021)—namely those that engage teachers in their own disciplinary activities—to support teachers' appropriation of tools that can help them challenge broader narratives that restrict who and what counts as engineering or STEM.

Background

A rich body of literature advocates the need for teachers to recognize and challenge dominant narratives about student ability, success, and belonging in our racialized, gendered, and classed society, particularly those narratives that directly impact them and their students (Bartolomé, 1994; Carter Andrews et al., 2019; Gay, 2010; Gutiérrez, 2013; Ladson-Billings, 2009). As part of becoming critical educators, teachers “knowing who they are as people, understanding the contexts in which they teach, and questioning their knowledge and assumptions are as important as the mastery of techniques for instructional effectiveness.” (Gay & Kirkland, 2003, p. 181). Researchers have argued that these processes of knowing, understanding, and questioning can be specific to disciplines, recognizing the ways in which critical perspectives intersect with STEM content (Dyches & Boyd, 2017; Morales-Doyle et al., 2020; Rodriguez, 2017; Sheth, 2019) and the political nature of these seemingly neutral and apolitical subjects (Gutiérrez, 2013; McGowan & Bell, 2020). For example, STEM disciplines like engineering have been historically narrowed in ways that benefit white, upper-middle class men. Teachers can perpetuate these narrow boundaries in their teaching through the opportunities they provide for students, what they value in their teaching of engineering, and whom they portray as engineers. Therefore, critically engaging with narratives is an important component to developing as a critical STEM educator (Tan, et al., 2021; Wright et al., 2020).

Efforts to support teachers' development as critical educators are often isolated to discipline-general courses or programs (King & Butler, 2015). These initiatives often encourage teachers to reflect on their own identities and positionalities, develop deeper connections to families and communities, and examine structures, practices, and discourses that marginalize students and their communities (Carter Andrews et al., 2019; Howard, 2003; Milner, 2003). There is a growing body of work on supporting teachers to engage with discipline-specific perspectives on becoming more critical STEM educators (Gutiérrez, 2013; Larkin, 2019; Patterson & Gray, 2019; Wright et al., 2020). For instance, STEM teacher educators have explored how to support teachers and teacher candidates to notice issues of race, class, and gender alongside students' disciplinary reasoning (Shah & Coles, 2020; van Es et al., 2017). Others highlight the importance of engaging with communities to identify resources and problems relevant for students' disciplinary learning (Morales-Doyle et al., 2020; Tan et al., 2021).

I argue that teachers' engagement in disciplinary activities is an underexamined site for supporting and theorizing their development as critical STEM educators. Given the limiting and often harmful ways teachers have experienced these subjects in their schooling (McGee, 2014; Mensah, 2019), there is a need to explore how teachers build connections between engagement in the "issues and practices of a discipline's discourse" (Engle & Conant, 2002, p. 403) with their own and their students' histories, identities, and cultural practices (Agarwal & Sengupta-Irving, 2019). These connections may provide opportunities to develop new, more critical relationships to disciplines, to their students, and to teaching (Olivares & Tucker-Raymond, 2020; Tan et al., 2021). In this paper I present the case of Alma to highlight these possibilities. While I do not have evidence of Alma fully developing critical or sociopolitical consciousness, I highlight productive beginnings in her process of becoming a more critical STEM educator through her participation in engineering design activities. In the next section, I detail a theoretical perspective for understanding how teachers can draw from their disciplinary engagement to start to develop critical perspectives tailored to their personal and professional contexts in ways that challenge narratives that restrict their students, their teaching, and their own relationship to the disciplines.

Theoretical framing

I take the perspective that teacher learning involves active navigation within and across communities of practice (Lave & Wenger, 1991). Teachers are embedded in school communities, make contact with disciplinary communities, and participate in professional learning communities. In these various communities, teachers encounter different narratives and discourses—all of which, as Rosebery, Warren, and Conant argue, are "inherently ideological; they crucially involve a set of values and viewpoints in terms of which one speaks, thinks, and acts" (Rosebery et al., 1992, p. 67). Learning, therefore, involves finding one's voice amidst these different perspectives. For example, Bakhtin (1981) describes how someone might uncritically traverse among different languages (church prayers, family conversations, government petitions), not recognizing connections or tensions in their ideological commitments and values. However, as one starts to acknowledge contradictions or coordination among these, Bakhtin argues that they will then "actively choos[e] one's orientation among them" (p. 296). In this paper I consider how a teacher's disciplinary experiences in a professional learning program supports her to "choose her orientation" among her different communities of practice—appropriating conceptual tools in engineering education to engage with the sociohistorical narratives that shape her teaching.

Appropriation

Disciplinary learning involves learning to take up the tools of a discipline in ways that hold meaning to both the disciplinary communities and learners' communities (Berland et al., 2016;

Manz, 2015). This learning involves more than just mastery—knowing how to use a particular tool—but also learning how to appropriate or “make a tool one’s own” (Bakhtin, 1981; Wertsch, 1998) in ways that relate to learners’ own stories and senses of self (Polman, 2006). Levrini et al. (2015) propose a definition of appropriation as “complex, reflexive process... of transforming [disciplinary] discourse (e.g., scientific words and utterances) so as to embody it in one’s own personal story” (p. 119). For example, they describe how a student, Michele, was focused on the idea that physics describes how objects in the real world work. In an interview, Michele repeatedly talked about engines, real objects, and what works. Further, this idea shaped his participation in his physics class: he took a pragmatic stance to different approaches to the laws of thermodynamics, often in contrast to a student who took more philosophical perspective. While the idea that physics explains how reality works is grounded in the discipline, it is also idiosyncratic to Michele, shaping how he participates in and reflects on physics activities.

To operationalize the construct of appropriation, Levrini et al. (2015) identify discursive markers that provide evidence of learners’ appropriation of disciplinary discourse and tools. These markers can help identify instances of appropriation in teachers’ talk about STEM disciplines and their classroom teaching. They consider how a repeated set of words or expressions are:

Marker A. *Idiosyncratic*—used in ways that were unique to individual students and not just repeated from an external authority;

Marker B. *Disciplinarily-grounded*—drawn on to build disciplinary knowledge and connected to the “rules and constraints” of the discipline (p. 118);

Marker C. *Thick*—involved in both metacognitive dimensions (e.g., shaping how they reflected on their disciplinary learning) and epistemological dimensions (e.g., shaping what it means to learn a discipline) of learning;

Marker D. *Nonincidental*—traced through multiple activities, beyond a single episode, to connect to a broader personal story;

Marker E. *Relational*—used to position one within communities in which the idea was developed; “inseparable from the classroom dynamics” (p. 118).

While Levrini et al. consider how learners transform discourse “to embody it in one’s own personal story,” these stories are never solely personal. They are shaped by the different narratives and discourses that people navigate in their lives. In this paper, I am interested in how a teacher appropriates disciplinary discourse in relation to broader sociohistorical narratives that shape how STEM disciplines are learned and taught.

Sociohistorical narratives

Sociohistorical narratives are “grand stories that connect to broader societal ideologies, stereotypes, and imaginaries.” (Gresalfi & Hand, 2019, p. 497). They are the often taken-for-granted overarching stories about society that shape how people make sense of the world, in moment-to-moment interactions and over time. While narratives are “situated in time and space” (Pawley, 2009, p. 310), they are also sedimented through history and the social constructs developed by that history, including race, gender, and class. For instance, a prevalent narrative in engineering is that some people are not “cut out” to be an engineer and that STEM courses need to “weed out” these students. As I unpack more later, this narrative was developed to imbue engineering with white masculinity as professional engineers’ preparation shifted from being “in the field” to in the classroom (Oldenziel, 1999; Secules, 2019). Notably, this “weed out” narrative intersects with other racialized, gendered, and classed narratives about who is “good at STEM,” merging together to gatekeep and marginalize people of color, women, and those from low socioeconomic backgrounds from engineering.

Teachers are navigating different narratives in their own learning and teaching (Louie, 2020; Philip, 2011). While developing awareness of these narratives is an important goal for teacher learning, they can shape teachers' and students' work even if they are not explicitly named (Leyva et al., 2021). That is because narratives are "enacted in social interactions in schools and classrooms as students are positioned (and position themselves) as learners or as certain kinds of learners" (Nasir et al., 2012, p. 286.). For instance, the "weed-out" narrative in engineering can be enacted when students and teachers organize classroom activities as opportunities to stratify students and identify who is "cut out for" engineering (Secules et al., 2018). Therefore, understanding what narratives are in play in teachers' interactions requires examining sociohistorical contexts of K-12 schooling in the United States and how STEM disciplines have been socially constructed over time.

Intersecting sociohistorical narratives of engineering and K-12 schooling

In this study, I explore how an elementary teacher, Alma, appropriated tools from her engagement in engineering activities to challenge dominant narratives about engineering and, more broadly, STEM. In this section, I nest Alma's story within the larger sociohistorical contexts of engineering and schools, highlighting the development of professional narratives of engineering as a discipline and how these narratives intersect with K-12 schooling. Alma is an experienced, white elementary school teacher in an "urban cluster" district centered around a small Southern city with a population of ~35,000. Her family was in the working class; she and both of her parents have worked at a local textile mill, while other members of her family have worked in construction. As the first member of her family to receive a college degree, Alma became a classroom teacher and eventually a STEM specialist at a local elementary school, seeking to create more hands-on experiences for her students to learn these subjects. These aspects of her personal narrative intersect with sociohistorical narratives about what is engineering and technology and how it should be taught in K-12 schools.

Sociohistorical narratives about what counts as engineering, what it means to be trained as an engineer, and who can be labeled an engineer can be traced back to the professionalization of engineering in the late 1800s and early 1900s. Through images, policies, and stories in popular media during this time, engineering and technology was largely positioned as the work of the white, male, able-bodied middle class (Frehill, 2004; Oldenziel, 1999; Riley, 2008; Slaton, 2010). For instance, the World's Fairs near the turn of the 20th century were a central site for negotiating what counts as technology in the United States. Exhibits showing the agricultural and domestic inventions of women, African Americans, and Indigenous peoples were separated from and positioned as "less evolved" than industrial machinery, such as the Corliss steam engine (Oldenziel, 1999). Relevant to Alma's personal narrative, the machinery of a textile mill was relegated to a "Woman's Pavilion" during the Philadelphia Centennial Expositions of 1876, minimizing women's roles in industrial life and as inventors (Oldenziel, 1999, p. 32).² This marginalization was exacerbated by the end of World War 1, when the World's Fair was organized to highlight cooperation between science, industry, and the military, positioning technology as solely produced by white male corporate scientists and engineers.

Alongside contestations of what counts as technology, there were debates about what is engineering and what is sufficient training to become an engineer (Frehill, 2004; Oldenziel, 1999). Professional societies and magazines further sought to establish it as a white, male, middle-class

²At the time, prominent women fought to even be able to curate a place for women's inventions at the Worlds' Fair; the Women's Pavilion was considered a progressive step forward for showing women's contributions. At the same time, this example shows how the narratives about who contributes to technology were negotiated through these public displays, even before the professionalization of engineering and shift toward higher education as a credentialing process. It provides a historical backdrop to understanding how Alma's family's work was excluded from engineering.

profession by deliberately excluding work of working-class machinists, seeking to enhance both status and pay of engineers (Frehill, 2004). In the mid-1800s, engineering training was primarily through field experiences, namely in the railyards or on the shopfloor, but by the turn of the century, higher education had become a central pathway for becoming an engineer. By situating engineering training in segregated colleges and universities, these policies restricted who could become an engineer along racial, gender, and class lines (Slaton, 2010). Frehill (2004) argues that engineering programs in higher education were informed by notions of hegemonic white masculinity at the time, in which engineering students needed to prove their worth by enduring stress and hardship in their coursework. For instance, Frehill references a series of articles in *Engineering News* in 1893 about the “Ideal Engineering School” in which the editors highlight military schools as a promising model, because they provide “incidental training in what we may call the manly and social accomplishments, [including] a certain practical gumption and physical vigor and training: an ability to put himself in unpleasant places calmly” (as cited in Frehill, 2004, p. 399). These narratives of masculinity clearly intersected with constructs of ability; indeed, at a national conference in 1907, Charles Thornberg, a professor of mathematics and astronomy at Lehigh University, suggested that engineers, like all other men, should have “a sound mind in a sound body.” (as cited in Frehill, 2004, p. 397). The history of the professionalization of engineering informs disciplinary narratives today—the profession continues to marginalize based on class, race, (dis)ability, and gender as reflected in the continued underrepresentation of Black and Hispanic graduates and women with engineering degrees (McGee, 2020; Riley, 2008; Slaton, 2010; National Center for Science and Engineering Statistics, 2019).

In higher education, dominant narratives continue to limit who is seen as an engineer and recognize only narrow forms of ability as part of engineering (Danielak et al., 2014; O’Connor, 2003; Pawley, 2009; Riley, 2008; Secules et al., 2018), despite the heterogeneity in the discipline (Faulkner, 2007; Suchman, 2000). Indeed, Gravel and Svihla (2020) recently highlighted how heterogeneous engineering involves coordinating the technical aspects with social and material dimensions, yet these are not often recognized in engineering education. These narrow visions of engineering have resulted in inequities based on race, gender, socioeconomic status, and ability, not just in terms of who graduates with an engineering degree (National Science Foundation & National Center for Science & Engineering Statistics, 2019), but also in compensation, belonging, and well-being in these fields (McGee, 2020; Riley, 2008).

This history of professional engineering is relevant to efforts to increase and improve pre-college engineering instruction (National Research Council, 2013). Recent implementation of engineering in K-12 classrooms reflects what has been historically privileged in professional engineering, with significant emphasis on using engineering design projects for students to apply science and mathematics content (National Academy of Engineering & National Research Council, 2009). Rather than creating space for students’ heterogeneity, engineering curricula often lead learners through highly structured, predetermined sets of activities with limited materials or space for creativity, often toward a particular science or mathematics canonical idea. Given the emphasis on integration of science and mathematics within engineering, “STEM” and “engineering” have often been conflated. While the disciplinary practices of science, engineering, and mathematics can be distinct, the meanings teachers, including Alma, make of these disciplines are often overlapping, particularly as related to the narratives about who is considered capable in “STEM.”

Furthermore, the increased inclusion of engineering in K-12 schools has coincided with intensified narratives of “accountability” in these spaces. The emphasis in the past few decades on “fixing” failing schools, teachers, and students reflects racialized, classed, and gendered narratives of control in public education (Golann, 2015; Morris, 2016; Taubman, 2009). Nationwide policies such as No Child Left Behind and Race to the Top required tracking students’ academic progress using narrow, quantifiable forms of measurement (Darling-Hammond, 2007). Extending historical

narratives of “blaming teachers” (D’Amico Pawlewicz, 2020), policy-makers, administrators, and curriculum developers continue to overly structure teachers’ work, “teacher-proofing” curriculum that results in teachers losing their autonomy in day-to-day classroom life (Crocco & Costigan, 2007; Milner, 2013).

In examining the intersections of these accountability—or control—narratives with the inclusion of engineering in K-12 schools, I contend the engineering design process (EDP) has served as a tool to structure and assess both teachers and students. While work in design studies have proposed different EDPs as a way to get a handle on how designers manage the complex, dynamic, ill-defined problem spaces (Atman et al., 2003; Dorst & Cross, 2001; Jonassen et al., 2006), distilling this for K-12 spaces has often led to straightforward, step-by-step representations of the EDP. While these simplifications may provide a more accessible framework for teachers new to engineering, the tradeoff is that the EDP can then become an efficient way to enforce narratives of accountability and control in K-12 engineering education contexts. Given the broader context of ongoing efforts to deprofessionalize teaching, integrated STEM and engineering curricula that structure lessons around leading teachers and students through the steps of the EDP can be seen as further limiting teachers’ professional autonomy and students’ agency (Strimel & Grubbs, 2017). In addition, particularly in school contexts in which Black and Brown children are disproportionately surveilled and policed, the step-by-step interpretations of the EDP can be used to further restrict what students can do and punish them for deviations from the steps. Therefore, rather than empowering (the predominately female) teacher workforce to foster meaningful engineering learning experiences or making space for marginalized students to find their place in engineering, the EDP can be used to restrict what is seen as engineering learning and, given the broader racialized, gendered, and classed contexts of U. S. schools, who can be successful in engineering.

I highlight the intersecting narratives about engineers and engineering and teaching and learning in U. S. elementary schools as a backdrop for understanding how Alma engages in professional learning and how she appropriates tools from engineering education—namely the engineering design process—to start to contest some of these narratives in her personal and professional life.

Study context

In 2017–2018, Alma enrolled in the Tufts Teacher Engineering Education Program (TEEP; www.teep.tufts.edu), an online graduate certificate program for in-service K-12 teachers. This program was designed to help teachers develop as knowledgeable and reflective practitioners in teaching engineering. Rather than training teachers around a given curriculum, the program sought to prepare teachers to identify, critique, adapt, and transform tools for teaching engineering. Focused on responsive pedagogy (Robertson et al., 2015; Thompson et al., 2016), a goal of the program was to attune teachers to recognize and support their students’ diverse resources for engaging in engineering. In the program, teachers take four courses over 18 months. The first and third courses address engineering design content, while the second and fourth courses focus on teaching and learning engineering (Figure 1). I helped design and teach one of the pedagogy courses, although I was not the instructor when Alma was in the program.

In the content courses, educators learn engineering as a knowledge-building discipline, in which engineers engage in “iterative cycles of decision-making” (Jonassen et al., 2014) to create artifacts that perform a specific function within constraints. Educators read and discuss resources about professional engineering, such as *The Design of Everyday Things* (Norman, 2002). They also participate in targeted lessons on key topics, such as simple machines, basic circuits, and computational thinking and programming. Their reflections on these resources and lessons were shared

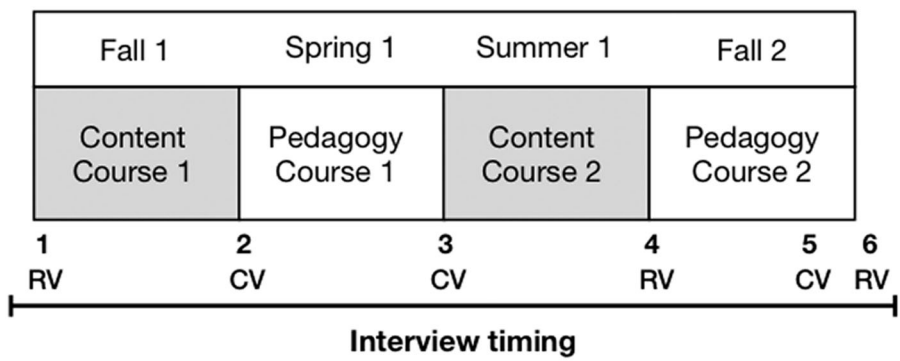


Figure 1. Timeline of TEEP courses and interviews with Alma. RV refers to when Alma viewed research videos in her interview and CV refers to when she viewed videos from her classroom.

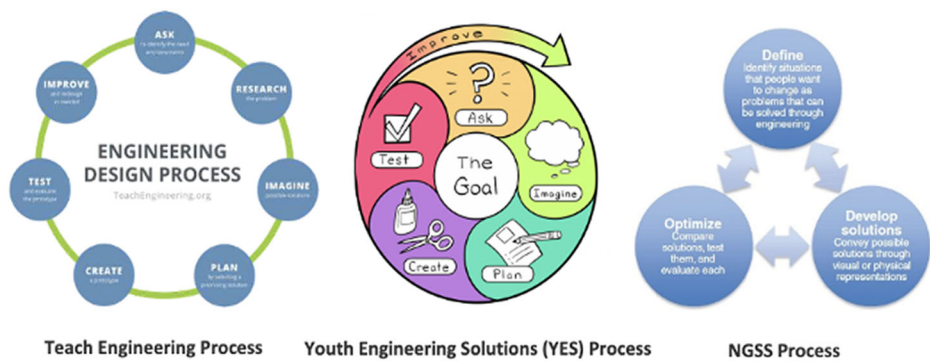


Figure 2. In Content Course 1, participants compared different representations of the EDP.

as *discussion posts*. For instance, in Week 4 of Content Course 1, educators shared discussion posts reflecting on readings that summarized differences between science and engineering.

In addition, educators also engaged in solving ill-defined, complex problems that are challenging for adult learners (as opposed to engaging in K-12 curricula.) These design labs typically asked educators to use LEGO Mindstorms EV3 kits, which included a programmable brick, sensors, and motors. In Content Course 1, the Week 7 lab was to build a robotic car that could follow a line using the light sensor. Each content course also had an open-ended final project that was scaffolded with deliverables over several weeks. For instance, the final project of Content Course 1 asked teachers to use LEGO robotics to design a robotic fish feeder for an owner that is traveling out of town. Educators shared their prototypes and design processes in *lab posts*. One goal for these courses was for teachers to experience engaging in the practices of the EDP as meaningful for their designing (Berland et al., 2016; Watkins et al., 2021). By posing challenging design tasks, educators experienced a need and purpose for framing a problem space, generating and realizing ideas, and interpreting physical feedback, which offered new opportunities for them to develop and adapt the practices of the EDP.

Rather than teaching participants to use a specific model of the EDP, the program looked at multiple different representations of the engineering design process from professional practice as well as representations created for pre-college settings (Figure 2).³ Participants compared the actions and sequences in the representations and discussed how well the model represented their

³Reproduced with permission from Youth Engineering Solutions (2021), TeachEngineering (2017), and National Research Council (2013).

own activity and process. These representations served as artifacts for discussing the ways in which their practices and processes differed from straightforward, step-by-step models often used in engineering education curricula.

The pedagogy courses were designed to foster a responsive approach to teaching. The courses foregrounded learning to listen for and recognize students' resources for doing engineering. Educators read and discussed resources on learning engineering, such as journal articles with data of students' engineering, summaries of pedagogical moves and practices, and synthesis lectures on topics such as design failures and planning. Each week they wrote reflections on these resources in *discussion posts*. The labs in this course were designed to support educators to practice eliciting, noticing, and responding to student thinking through student interviews and online video discussions (Watkins & Portsmore, 2022). They also had opportunities to plan lessons, evaluating and designing activities with attention to different aspects of engineering and students' thinking.

The program offered several affordances for teachers' appropriation of disciplinary and pedagogical tools for their own purposes and contexts. The program was offered asynchronously and the national and international teachers who enrolled taught in diverse contexts and with a wide variety of student populations. The program encouraged teachers to make sense of their learning in the program within their particular teaching contexts. To engage in the course discussions, there was a need to make this sensemaking explicit to others who were teaching in very different roles and with different student populations. The responsive nature of the program, including tailored, individualized feedback on course assignments, reinforced the importance of teachers' personalizing their learning with course instructors. Furthermore, the content and pedagogy courses presented multiple epistemological perspectives on design and design pedagogy. In reading reflections and assignments, there were opportunities for teachers to position themselves within those perspectives, such as by asking teachers to create their own representations of the engineering design process to reflect their learning through engaging in design tasks.

Critically, the program offered only a few opportunities for reflection or critique of dominant narratives in engineering, particularly about who is seen as an engineer, what counts as engineering, and toward what ends engineers work. A couple of readings and course discussions in the pedagogy courses addressed the funds of knowledge that students from marginalized populations might bring to engineering and how engineering might serve to disrupt narrow characterizations of ability in STEM, but these activities were limited in duration. [Supplemental Materials Tables 1 and 2](#) provide additional details on course readings and activities.

Data collection

Eleven elementary teachers in the 2017–18 TEEP cohort were recruited to participate in an initial study examining shifts in teachers' responsiveness over the course of the program. Each participant consented to participating in research interviews, allowing researchers to analyze their program coursework, and collecting videos of students' engagement in engineering from their classroom. Alma was interviewed by a consultant on the project, who was not involved in the teaching or design of TEEP and has extensive experience in interviewing and qualitative research methodologies in physics education. After each round of interviews, the research team met to discuss themes in the teachers' reflections about teaching and learning engineering. Alma's story stood out early in our debriefs. She developed a close relationship with her interviewer, sharing not only her experiences in TEEP and in her classroom teaching, but the connections she was making to her personal life. Her openness challenged me to expand how I was conceptualizing teacher learning in the program, to consider not just shifts in her understandings of engineering, her pedagogy, or even her identity as a teacher of engineering, but how she was making sense of the past, present, and future for herself, her family, and her students.

Research interviews

Alma was interviewed six times over the course of TEEP: at the start and end of the program and after each of the four courses (Figure 1). These interviews were designed to address our original research questions focused on examining teachers' goals for teaching engineering and responsiveness toward students' thinking in classroom engineering activities. Each interview lasted about 2 hours and was conducted over web-conferencing software (Skype). To prioritize relationship-building, the interviews were semi-structured and conducted in a conversational manner with the same researcher. In the first interview, Alma was asked about her teaching and educational background, as well as questions about her goals for enrolling in TEEP. After each course, Alma was asked to talk about her experiences in the course and the significant things she learned. In the final interview, she was asked to reflect on her experiences in the program and changes in her teaching practice.

In each interview, Alma watched and discussed videos of classroom engineering, answering the question: "What do you notice in the video that is relevant for you as a teacher of engineering?" In the first and last interview, Alma watched the same two videos. In the other interviews, she watched and discussed videos she collected from her classroom (Interviews 2, 3, and 5) as well as one other video from our research collection (Interview 4). I focus in this paper on her responses to our research videos (Interviews 1, 4, and 6) because they were selected as examples of substantive student reasoning about activities in the engineering design process (see [Supplemental Materials Table 3](#)). These videos consisted of students interacting with each other and their artifacts to make sense of how they addressed a design problem. Our team of engineering educators identified several design practices within each video, such as rapid prototyping, imagining how a design will be used in context, and identifying key design features that impacted its performance.

Coursework

To consider both her engagement in doing engineering herself and her reflections on engineering design in her program coursework, I archived Alma's discussion and lab posts in the content courses. She had 20 (11 and 9) total discussion posts and 26 (15 and 11) lab posts in Content Course 1 and 2, respectively. I also looked at her final project in Pedagogy Course 2, as a culmination of her work in the program.

Analytic methods

An initial goal in our broader study of teacher learning in TEEP was about fostering and examining teachers' responsiveness to student thinking in engineering. I was PI of this research study and led a team to conduct the interviews and analyses of how teachers attended to student thinking. In debriefing conversations with Alma's interviewer, a consultant on the project who had developed a personal relationship with Alma, it became clear that understanding Alma's learning in the program went beyond shifts in her pedagogical responsiveness but involved epistemological and affective aspects of her engagement in engineering, her empowerment to reframe her and her family's identity in STEM, and her sense of agency in her school and community. These conversations led to the post-hoc research questions that I focused on: (1) what conceptual tools Alma appropriated from her engagement in engineering and (2) how she drew on these tools in ways that challenge dominant narratives of engineering, STEM, and school.

I was not Alma's teacher nor her interviewer; however, I did help design the pedagogy courses in TEEP. Given this involvement, I deliberately considered aspects of Alma's reflections and learning that differed from the stated program goals, often with the help of Alma's interviewer who was not involved in the program. In addition, since my questions center on how Alma

contested dominant narratives, I recognize that my experiences, values, and perceptions as a white female scientist, science and engineering education professor, and university teacher educator offer affordances and constraints in both recognizing those narratives and expanding what counts as disciplinary learning and teacher learning. Reflecting on my positionality, I draw on histories of engineering and its relation to K-12 schooling to reflect on how my own educational experiences and positions in universities could privilege particular forms of credentialing, learning, and teaching in STEM disciplines, and marginalize others.

Initial analyses of the transcripts and coursework

I first read through all interview transcripts and discussion and lab posts, identifying excerpts that provided evidence of Alma's evolving relationship to engineering; that is, how she was positioning herself in (or out of) the discipline, engaging in engineering, and framing what it means to do engineering with her students and others. I coded for excerpts in which Alma either (1) positioned herself in relation to the discipline of engineering, (2) discussed her engagement in doing engineering, (3) reflected on what she learned from doing engineering and what connections she was making to her life outside of the program, or (4) discussed her goals and practices for teaching engineering.

I then developed analytic memos characterizing and summarizing the excerpts from Alma's early experiences in the program (Content Course 1 and Interviews 1 & 2) and her later experiences (Content Course 2 and Interviews 3–6). In comparing these narratives, a central theme emerged related to shifts in how she engaged in and talked about the EDP. For the next phase of analysis, I examined whether and how Alma appropriated discourse of the EDP through her participation in engineering and how this appropriation was connected to sociohistorical narratives of engineering and K-12 schooling.

Identifying instances of appropriation

To look for evidence of Alma appropriating discourse of the EDP, I identified specific words and phrases of the EDP that she transformed over the course of the program. First, in her lab and discussion posts and her interviews, I looked for repetition of similar words or phrases that described an idea she developed through her participation in engineering. I then coded for evidence of appropriation using the discursive markers developed by Levrini et al. (2015). Note that the collective presence of these markers offers evidence of appropriation by a learner, but analysis must also consider the local and broader contexts to make meaningful interpretations (e.g., whether an idea was heavily scaffolded by an interviewer or whether an idea is idiosyncratic in the learning community).

Marker A. *Idiosyncratic*—I looked for repeated words and expressions that Alma used that I did not see other teachers use extensively in their interviews or coursework. I also confirmed my observations with the other interviewer and course instructors. For instance, toward the end of TEEP, Alma repeatedly referred to the EDP as “going every which way,” which was distinctive to her. I also considered whether these phrasings were word-for-word repetitions from an authority (e.g., from readings, instructors, K-12 engineering curricula). For instance, at the beginning of TEEP, Alma repeatedly used the exact words of an EDP from a popular curriculum; this would not be considered evidence of appropriation. I drew on my experiences teaching in the program and interviewing other teachers and debriefed with Alma's instructors to confirm whether an idea/phrasing was unique to Alma.

Marker B. *Disciplinarily-grounded*—to consider how Alma's ideas were connected to the discipline, I considered my personal experiences as an engineering educator and scientist, reviewed literature on the nature of engineering design, and consulted with other engineering educators. I also looked to the literature for more expansive ways of defining the discipline, particularly the heterogeneity inherent in the discipline (Bucciarelli, 1994; Faulkner, 2007; Stevens et al., 2014; Suchman, 2000).

Marker C. *Thick*—to consider whether there were metacognitive and epistemological dimensions to Alma’s appropriation, I noted how Alma used her ideas about the EDP to make sense of her engineering tasks in lab assignments and how she later evaluated her approaches in reflections.

Marker D. *Nonincidental*—I looked for evidence of Alma’s idea across contexts and data sources, including her lab posts, discussion posts, and interviews.

Marker E. *Relational*—since the asynchronous nature of TEEP meant there were fewer student-student interactions, I primarily considered whether and how Alma used her expressed idea to position herself in both lab and discussion posts. For instance, I looked at how she used this idea to narrate herself and her learning to her peers in her discussion posts.

Identifying connections to sociohistorical narratives

Once I had identified a central idea that Alma appropriated from her engagement in doing engineering design, I looked for evidence of how she used this idea as a tool in relation to sociohistorical narratives. Given that neither the program nor the data collection were focused on teachers’ recognizing and disrupting sociohistorical narratives of engineering, STEM, or school, the interviewer did not ask Alma to explicitly discuss these narratives. However, regardless of her awareness, sociohistorical narratives can still be present in interactions, shaping how she positions herself, her family, her students, and the tools of the discipline (Leyva et al., 2021; Nasir et al., 2012). Therefore, to identify how narratives might be at play in Alma’s interactions, I reviewed literature on the development of engineering as a discipline and how it intersects with critical dimensions of K-12 schooling in the United States. I summarized key dimensions of this literature in the section above. Based on this review, I identified instances in Alma’s talk that connected to the histories and narratives of engineering, STEM, and K-12 schooling.

Looking back over the excerpts I selected from Alma’s participation later in the program, I identified instances in which there was both evidence of Alma appropriating the EDP and language of resistance in relation to how she or others (hypothetical or real) had interpreted what (and who) counts as engineering or STEM in and out of school. Evidence of this resistance language included when she challenged her earlier thinking: “I wouldn’t have ever imagined ...” or “That’s changed my mindset a bit.” I also documented when she recounted interactions with others in which she pushed back on how they positioned engineering or STEM learning, such with as a colleague or her son’s teacher: “And I’m like, no, we don’t want to start there...” There were also times in which she referenced not a specific person, but a hypothetical one: “You can’t tell me...” or “I’ll be voicing that forever as long as I’m alive.” I then analyzed how her appropriation of the EDP served as a tool to push back on particular narratives.

To support the trustworthiness of my claims, I debriefed my analyses with the broader research team—two of whom had been Alma’s instructors. We met to discuss the different forms of evidence and consider multiple interpretations. For instance, we considered whether Alma’s discourse reflected significant transformation from a lecture on the EDP in Content Course 1. Early in the analysis, but after she had completed the program, I also member checked my interpretations with Alma, who confirmed the interpretation that a significant shift for her in the program was how she drew on the EDP in her learning and teaching.

In TEEP: appropriating the EDP through engagement in engineering design

In this section of the findings, I address the first research question posed at the start of the paper which focused on understanding what conceptual tools Alma appropriated through her engagement in engineering design. Drawing on interviews, lab posts, and other coursework, I analyze how Alma discussed engineering teaching and learning, engaged in engineering activities herself, and approached teaching engineering (Table 1). Alma, like all teachers, traversed different

Table 1. Evidence table for characterizing Alma’s appropriation of the EDP discourse, including descriptions of the activities in which she used EDP discourse, claims about how she drew on this discourse at the beginning and end of the program, data sources used to support these claims, and timing of relevant instances.

Activity in which Alma drew on EDP discourse	How Alma drew on the EDP	Data sources	Relevant Instances
<i>Early in the program (Content course 1 before final project)</i>			
Discussion of engineering teaching and learning	Alma repeats the exact steps and order of the EDP as integral for teaching and engaging in engineering.	Discussion posts; interviews	Content Course 1 Weeks 2, 3, 5, 6 Interview 1
Engagement in engineering design	Alma made sense of her engagement in engineering by relying on exact steps and order of the EDP.	Lab posts; interviews	Content Course 1 Weeks 4, 5, 10
Pedagogical reasoning in engineering	Alma’s reliance on the EDP constrains what she planned for and noticed in students’ engineering.	Lesson planning; noticing of classroom videos	Interview 1 Video Discussion Interview 2 Lesson Planning Content Course 1 Week 2
<i>Later in the program (End of content Course 1—pedagogy Course 2)</i>			
Discussion of engineering teaching and learning	Alma emphasizes that the EDP is nonlinear and encompasses diverse jobs.	Discussion posts; interviews	Content Course 1 Final Project Content Course 2 Weeks 1, 2, 3 Interviews 2, 3, 4
Engagement in engineering design	Alma made sense of her engagement in engineering by recognizing the fluidity of the EDP.	Lab posts; interviews	Content Course 1 Weeks 11, 12 Content Course 2 Weeks 2, 3, 6, 7, 11
Pedagogical reasoning in engineering	Alma’s recognition of the nonlinear and diverse nature of the EDP expanded what she planned for and noticed in students’ engineering.	Lesson planning; noticing of classroom videos	Interview 3 Lesson Planning Interviews 4 & 6 Video Discussion Pedagogy Course 2 Final Project

communities in her continued professional learning, including her school community, prior professional development programs, and TEEP. In my analyses, I argue that at the start of the program, Alma repeated discourse of the EDP from a prior professional development program but had not yet made it her own. Over the course of the program, I show how Alma started to appropriate the EDP—developing an idiosyncratic perspective on the EDP to make sense of engineering design and to shape her participation in engineering activities. Then, in the next section, I will analyze how her appropriation of the EDP expanded dominant narratives about who is considered an engineer and what counts as engineering teaching and learning.

Early in the program: echoing EDP discourse

Alma’s first interview took place at the start of the program, after only a couple weeks of coursework. In this interview, Alma highlighted the engineering design process—the steps and sequence—as an integral part of how she taught engineering. Pointing to a poster in her classroom, she described: “It’s hanging right up over here above my bulletin board... I refer to that all the time” (Interview 1). This emphasis was echoed in her discussion posts during Content Course 1, in which she named the specific steps and order from a popular elementary engineering curriculum, rarely deviating from the exact words used in the lessons. Alma wrote: “At the elementary school level, a student should be taught how engineers think by being taught the engineering design process, and its steps thoroughly. These steps include: ask, imagine, plan, create, improve, and communicate” (Content Course 1, Week 2 discussion post). The EDP was also

how she positioned who is an engineer in her Week 3 discussion post: “Engineers are people who follow a process of design, improve their designs, and then reflect on what they have designed” (Content Course 1, Week 3 discussion post).

Looking at her lab posts early in Content Course 1, there is evidence that Alma made sense of her disciplinary engagement based on the exact steps and sequence of the EDP. For instance, in the Week 5 lab, she described her participation in terms of whether she followed the EDP: “I found myself going through the engineering design process to figure out which design would show some success.” She also evaluated her engineering activities based on whether she followed the sequence of the steps. In Week 4, teachers were asked to use the LEGO Mindstorms kit to make a robotic car; this was their first opportunity to use the programmable brick—a tiny computer inside a Lego pocket-sized brick—as part of their designs. Alma did not have any experience with these materials prior to the course, and she reported that this task was a challenge. In her lab post, she again focused on the steps of the EDP:

So, I did go through the engineering design process. [However] I tried to create though before planning, and it obviously didn’t work... I was then able to create the Riley Rover... I decided to improve the design by adding the ultrasonic sensor. (Course 1, Week 4 lab post)

In this excerpt, Alma made sense of her participation in the engineering task in terms of going through the steps of the EDP. She repeated the exact words from the EDP used with her students (“create,” “plan,” “improve”) to describe her activities. Notably, she evaluated her designing based on whether she adhered to the sequence of the steps of the EDP—attributing her difficulties because she “create[d]” before planning. While planning first may have helped her get started on her design, it also may be the case that she needed to create to become familiar with the materials first (Gravel & Svihla, 2020; Portsmore, 2009). Regardless, her use of the word “obviously” suggests that the productive ordering of design activities is fixed, based on the predetermined sequence in the EDP.

Connecting back to her teaching, there is evidence from Alma’s discussion of classroom videos that she also made sense of students’ engineering in terms of the exact steps and sequence of the EDP. In Interview 1, Alma was asked to watch two videos of classroom engineering, selected from prior research projects. While these videos were chosen to show multiple aspects of students’ design activities, Alma zeroed in on what step the students were on in the engineering design process:

That appears to be, to me, the communication part. Am I correct on that? If you’re looking at the engineering design process: ask, imagine, plan, create, improve, communicate. Is that the communication step, that they were just doing? (Interview 1)

She posed a similar question to the second video: “So this is the communication part again? Right?” Before commenting on what she noticed in students’ work, she used the steps and sequence of the engineering design process from a popular curriculum. Further, her focus on the correct step of the EDP obscured the other productive aspects of students’ engineering work that she did not attend to, such as students’ problem-scoping, consideration of tradeoffs, and mechanistic reasoning. While the EDP had become a familiar tool that she uses extensively in her teaching, she applied it rigidly to students’ work, imposing the words, sequence, and structure to interpret students’ work and therefore missing the rich dimensions of students’ engineering present in the videos.

Summary

Discourse around the engineering design process is prevalent in K-12 engineering education; there are multiple curricula and resources that emphasize the need for students to be led routinely through a set of steps to gain access to the engineering discipline. This discourse is both epistemological and ideological (Rosebery et al., 1992): it conveys values and assumptions for

how engineering knowledge is produced, how students should be positioned in engineering tasks, what opportunities should be made available for students' agency, what resources should be available to them, and who has access to the label of "engineer."

From her prior experience from professional development and teaching engineering, Alma was familiar with the discourse of the EDP and used it consistently as a tool in her teaching and in her engineering. This tool shaped how she interpreted her and students' engagement in engineering. Alma repeatedly referred to the EDP when she talked about engineering (Marker D), including how she evaluated her own engineering engagement (Marker C) and positioned herself in her coursework (Marker E). However, she rarely deviated from the words in the curriculum; her use of the same exact phrases suggested that the EDP was yet to be "her own" (Bakhtin, 1981). There was not evidence that she had appropriated it to develop her own idiosyncratic idea or perspective (Marker A). Furthermore, the emphasis on discrete steps in a linear process deviates from descriptions of professional engineering practice (Marker B). In summary, I argue that at the start of the program, Alma had taken up a particular discourse in engineering education, but in ways that both differ from disciplinary norms of engineering and suggest that these words are not yet her own, not yet populated with her own purposes and perspectives (Bakhtin, 1981). She drew on this discourse to make sense of her own engagement in engineering as well as students' engagement, in which she structured and evaluated engineering in terms of whether the steps were followed in order.

Later in TEEP: appropriating EDP discourse

For her final assignment on the fish-feeder project for Content Course 1, Alma was asked to reflect on her design process in a discussion post, contrasting it with the one she created earlier in the course:

I definitely evolved from what I had originally shared at the beginning of this course. I had originally stated the Engineering Design Process included the following steps: Ask, Imagine, Plan, Create, Improve, and Communicate. As you can see from my diagram, I was jumping from one stage to the next to create this fish feeder prototype. Doing this project changed my mind of how the process actually works. It can skip from one step to another, go backwards, go forward, and so forth. (Content Course 1, Week 14 discussion post)

While Alma repeated the steps of the EDP, she now populated her discourse about this process with language describing the unpredictable, nonlinear process of designing (Marker B). Alma referred to "jumping from one stage to the next" and considers how the EDP "can skip from one step to another, go backwards, go forward." She used similar words across multiple interviews to describe the EDP, describing how she had to "go back" and "bounce" between steps—she was unique among our interviewees in emphasizing this discourse (Marker A). In Interview 2, which took place a month after this final reflection, Alma expanded on how she was transforming the discourse of the EDP to make sense of her own engineering and to teach engineering differently (Marker C):

Well one of the things that I found out in this course and it was really hard for me to kind of break free from it, was that those steps, they don't always go in that order. They go a little bit everywhere. Because I was doing that [final project] and it was like, ok, I had to ask myself, how am I going to build this thing? I was just kind of imagining things in my mind, what it would look like ... But I did find as I was creating, that I was going back and I was kind of like, wait a minute, this won't work this way, so I'm going to have to go back now to the ask part ... And then I was going back to the asking and imagining again and then I was planning it out again, adding to my drawing that I'd done ... Then I got feedback back from my colleagues and then I was going back to [the] asking phase. [I]t was all over the place. It was nothing like that [pointing at the EDP representation in her classroom] ... [The EDP] goes all over the place. It doesn't have to go in that order ... [B]ut I find myself telling my kids, now it doesn't have to go in that order. It can bounce and go all over the place. (Interview 2)

Again Alma drew on the steps of the EDP to reflect on her engagement in engineering—using the terms “ask,” “imagine,” “plan,” and “create” as she did at the start of the program—but now she referenced these steps in terms of their flexibility and how they can help her make progress on her design. Notably, she also changed how she talked about the EDP with her students, now emphasizing that they do not have to be in order but can “bounce” between different activities, reflecting that this idea is nonincidental for her (Marker D).

In addition to acknowledging the nonlinear nature of engineering, Alma also drew on the EDP to reflect the different jobs that engineers can do, such as quality control, manufacturing, and research engineer, modifying a peer’s assignment to make a poster for her classroom:

I actually put this up on a bulletin board ... it goes through the engineering design process and the types of engineers that are involved with that. ... a research engineer would ask; um, a development engineer would imagine; a design engineer would plan; manufacturing, construction, operations, and maintenance would be create, testing, analyze; quality control would be improve; technical support, customer support, sales, consulting is communicate; and systems and management would be collaborate (Interview 4)

Rather than positioning engineering as a solely technical pursuit, as is often the case in engineering education (Hynes & Swenson, 2013), Alma drew on the EDP to mark the heterogeneity in engineering practice (Gravel & Svihla, 2020; Law, 1987; Suchman, 2000). Recognizing engineering as encompassing different kinds of jobs and different kinds of people, Alma started to position herself as a particular kind of person in the EDP—a “systems-type” person—suggesting that this appropriation of the EDP supported her to start to see herself in new ways in engineering.

Looking at her lab posts from the final project in Content Course 1 and in Content Course 2, there is further evidence that Alma engaged in engineering as a process of figuring out what to do to make progress in her design (Marker D) and used that to position herself in her shared posts (Marker E). In her reflection on her final project from Content Course 1, she described how she evaluated what to do in her design process based on what was working and what was not—freeing herself from having to follow the exact sequence of the EDP (Marker C). Instead, she based her decisions on what she thought would help her make progress: “I decided that I need to begin this process by doing some research first...” (Week 12 lab post). In contrast to her earlier labs, she did not use the steps and order of the EDP as her primary justification or evaluation for her actions, instead she justified her activities based on what she thought she needed to do.

This shift in Alma’s engagement in the engineering design process was especially salient in Content Course 1, as she explicitly reflected on the EDP more often in her lab posts. In Content Course 2, she made fewer references the exact steps and order of the EDP (Table 1). Instead she often described her design activities in more general terms: “I decided to create my electrical circuit first. After I was able to get the electrical circuit built then I began experimenting with a way to create a switch.” (Content Course 2, Week 6). When she did reference the EDP, she no longer expected to proceed linearly through the process. For instance, in response to her final project in that course, she anticipated the need to navigate between different steps:

I have a general idea of what I want it to do and look like, but I’m not sure if my idea will work until I begin the creation stage and try building it and troubleshooting. I guess I need to tinker with the pieces and see what works and what doesn’t. (Content Course 2, Week 9 lab post)

Again Alma referenced a particular step from the EDP—create—but situated it in a much more fluid process of seeing how her plans can be realized, tested, and improved, reflecting a stronger grounding in the discipline of engineering (Marker B). Instead of a linear process, she anticipated the need to “tinker” to figure out how the pieces might work together. In her final reflection on this project, she described her process as nonlinear, tackling new problems as they arose in the course of her designing.

Connecting back to her teaching, Alma's appropriation of the EDP impacted how she made sense of students' engineering activities. In Interview 4, after Content Course 2, Alma watched another research video showing students working together to develop different solution plans. In contrast to the first interview in which Alma used the EDP as a tool to specify the step that the students should be on, here she noticed multiple aspects in their work.

You know, they're going through a lot of steps of the engineering design process already right there in the video. ... they're asking questions, definitely. They're imagining, they're planning out, they're drawing. They've made a creation with the pencil going on top of the bottle. They're talking through and trying to improve how both ideas could work. They are communicating. They're doing everything right there in that video. (Interview 4)

While Alma drew on the steps of the EDP to evaluate students' engineering, she did so in a way that reflected the overlapping, dynamic nature of these design activities. With her appropriation of the EDP, she was able to value more of students' work, seeing beyond a particular step in a sequence to notice their complex design activities in context (Markers C & D).

In the last course of the program, Alma was asked to plan an engineering unit, in which there is further evidence that she drew on her appropriation of the EDP in her teaching. For instance, rather than positioning the "Communicate" step at the end of the EDP (as she had at the start of the program), she planned for students to share their prototypes at multiple points: "Kids need to talk about their prototypes more than once with the whole group." (Week 9, Pedagogy Course 2). Furthermore, in her final project, she used a more fluid conceptualization of the EDP in her lesson plan, anticipating that her students would need flexibility to move between steps of the EDP and providing time for them to do so.

Summary

In contrast to her initial use of the EDP that strictly adhered to the depiction in a popular curriculum, by the end of the program there was evidence that Alma appropriated the discourse of the EDP to develop the idea that engineering is nonlinear, dynamic, and heterogeneous. Across interviews and courses posts, Alma repeated words that linked together to express an "authentic, idiosyncratic signature idea" (Levrini et al., 2015, p. 118)—an idea that was not just repeated from the course and that was unique to Alma among the participants interviewed (Markers A & D). It was more disciplinarily grounded than her linear depiction of the EDP, reflecting the dynamic, messy process of solving ill-defined problems (Jonassen et al., 2006), which speaks to what it means to engage in engineering (Markers B & C). Lastly, this idea was used in her lab posts to plan, justify, and evaluate her designing; the development of this idea was entangled with how she positions herself in the design tasks (Marker E).

Across contexts: appropriating the EDP to contest narratives about STEM and school

Thus far I have documented a shift in how Alma made sense of her own and students' engagement in engineering design and how this shift is connected to her appropriation of discourse of the engineering design process. These findings point to her developing more nuanced and authentic understandings of engineering design and to her transforming the language of the EDP often seen in elementary curricula to fit her particular contexts of learning and teaching. In some ways, this analysis could show a rather straightforward development of Alma's disciplinary expertise: by the end of the program, she was more flexibly using a conceptual tool of engineering—the EDP—in ways that supported her to make progress in her disciplinary activities and to make sense of what it means to do engineering. For teacher education programs, including this

one, achieving this kind of reframing is a meaningful goal for engaging teachers in their own disciplinary pursuits.

However, Alma's story does not stop at how she made sense of her experiences within TEEP. Importantly, in her appropriation of the EDP, she started to challenge to some of the dominant narratives that have shaped her teaching and learning. In this section, I extend the analysis to consider how she weaved together her reflections of her professional learning, personal family history and imagined futures, and school experiences as she appropriated the EDP. By transforming the discourse of the EDP to consider how it is nonlinear, dynamic, and heterogeneous, she navigated and challenged some of the dominant narratives about STEM and school, including narratives about what counts as engineering that have restricted her and her family from being recognized as engineers, and narratives about control in schools that have shaped her teaching and colleague interactions. Note that while my analysis parses how Alma appropriated the EDP to show first how she made sense of her engineering learning and teaching and then to show how she started to challenge dominant narratives, these processes were linked both conceptually and in timing.

Expanding what counts as engineering and STEM: renarrating her family's past and her son's future

In Interview 1, when Alma was asked about her prior experiences with engineering, she at first said that she had no experience other than what engineering projects she had taught in her classroom, but then she noted that she and her family had worked in a textile mill. Alma acknowledged the hard work and skill that was needed to make the blankets they produced and how her experiences were a central part of her life story before going to college. However, she expressed uncertainty about whether this work would be recognized as engineering.

As described in the previous section, after Content Course 2, Alma began talking about the EDP as a way to highlight the different functions of engineering, developing the idea that the EDP shows the heterogeneity in engineering. In the same interview, she appropriated this idea as a conceptual tool to position her family's work within engineering. I include an extended quote here because it shows how she linked the EDP to her work in a textile mill:

I actually put this up on a bulletin board, this in my room, but it goes through the engineering design process and the types of engineers that are involved with that... But like a research engineer would ask; um, a development engineer would imagine; a design engineer would plan; manufacturing, construction, operations, and maintenance would be create, testing, analyze; quality control would be improve; technical support, customer support, sales, consulting is communicate; and systems and management would be collaborate... I didn't realize there were that many types of engineers. And you know, before I started teaching school, I worked in a factory. I worked in a factory that my parents worked in. We worked in a textile mill and I even told the professor of this course, I was like, you know what, I didn't realize this, but I was an engineer before I started teaching. Because I was a, I was a weaver on looms... My parents worked there for 30 years. It was like, I didn't realize it, but my dad was even an engineer because he had to fix the looms. He was considered to be a loom fixer. And then mom, she was a supervisor, so it was like she was the engineer on this job as well. So I actually that it was interesting. I just thought it was amazing. I connected to that. And I even pointed that out in my essay this summer, is why. I couldn't have, I wouldn't have ever imagined I would have been classified as an engineer, but now I see it. Before I didn't. (Interview 4)

In the first part of this quote, Alma elaborated on how the EDP can reflect the myriad functions of engineering, appreciating that she hadn't realized there were many different types of engineers. Alma then made a connection to her history working as a weaver in the textile mill. Drawing on the different descriptions of jobs within the EDP, she positioned herself and her parents as engineers based on the job responsibilities they had. In her course

discussion post (Week 2, Content Course 2) she expanded on how she saw her family as manufacturing engineers. She and her mother both had worked to “create” blankets by running 18 looms at a time; later her mother supervised others on the looms and Alma started work as a textile designer. Her father worked to repair the looms and later worked on quality control—jobs she linked to the EDP as “create,” “test,” and “improve.” She also talked later in the interview about how other family members who worked in construction were structural engineers.

I argue that the quotes from her interview and her course discussion post are evidence that she appropriated the EDP to redefine her and her family’s work history. She drew on the idea that the EDP represents a heterogeneity of functions to position her family’s work in textile mills and construction as engineering. In doing so, she started to contest narratives about what counts as engineering, which served to disrupt dominant classed (and racialized) narratives that engineering excludes the work of working-class technicians and construction workers. While I do not have evidence that she was aware of this history, Alma’s re-classification of her family’s work as engineering harkens back to the textile machinery being relegated to the “Women’s Pavilion” in the 1876 World’s Fair—and eventually removed from the Fair entirely by the end of World War 1. By including working on looms and designing fabrics as a part of engineering, she was (tacitly) contesting these gendered narratives of engineering and technology. These contestations led her to reconsider her earlier personal narrative of herself as not an engineer: “I wouldn’t have imagined I would have been classified as an engineer, but now I see it. Before I didn’t.” At the start of the program, Alma did not consider herself in engineering, but by appropriating the EDP through her engagement in engineering design activities, Alma started to expand who can be seen as an engineer, recognizing more of herself in the discipline.

There is also evidence that Alma drew on this more expansive idea about what counts as engineering to contest what counts as “STEM” in schools, particularly in imagining her son’s future. In Interview 5, Alma described her son’s skill at fixing the front of their garage over the summer, contrasting this work with his academic struggles in the eighth grade. Referencing his label as “on the autistic spectrum,” she argued that the traditional academic performance opportunities were limited in showing what her son could do and what is future would be like. She pushed back on what the school’s marker of “fourth-grade math level” meant for her son’s competence by recounting how he had saved money from his monthly allowance to buy wood for the garage, demonstrating his financial planning and persistence. She described how he planned the project, highlighting his abilities for measurement, frame construction, and decision-making. She used this example to push back on the ways school positions him: “You can’t tell me that he’s not smart.” She talked about the importance of school to help him see his potential, again taking up the label of engineering, or in this case “STEM,” to describe his possible future:

If he can see where he’s going to be, learning in a technical somewhere or working with a construction worker, learning how to be a construction and be better prepared for it. He’s going to work on cars. He’s going to do something like that. That is still STEM.

Just as she took up the label of engineering to re-narrate her family’s history working in a textile mill and in construction, she took up the label of STEM to value what her son can do, in contrast to the label available to him at school. In particular, she challenged notions of “ability” in STEM, disrupting embedded notions of ableism in narratives of who can be an engineer, particularly in school. Highlighting the hands-on aspects of STEM that have not been recognized in his school experiences, but that she had seen as part of the EDP, she re-imagined her son’s future working in a STEM field.

These two examples provide evidence of how Alma appropriated the discourse of the EDP to expand what counts as engineering, and later STEM. Drawing on the idea that the EDP reflects the heterogeneity inherent in the discipline, Alma challenged ideological values and assumptions

about who has access to the label of engineer. In contrast to her early conceptualizations that positioned engineers as people who follow particular steps, she later challenged this classification, whether those steps are within an EDP or are a part of an academic path through a four-year university. Her reconceptualizing of what it means to learn engineering allowed her to start to challenge the classed, gendered, and (dis)abled aspects of the dominant narratives that limit how she sees herself and her family in the discipline.

Reconsidering how engineering should be taught in elementary classrooms

In addition to expanding what counts as engineering or STEM, Alma also appropriated the EDP to push back on dominant narratives of control in K-12 schooling. Drawing on her appropriation of the EDP to highlight its nonlinear and unpredictable nature, she reconceived her engineering lessons and advocated for students to be positioned with agency to decide how to proceed in their material explorations. For instance, when her school acquired Ozobots, programmable robots designed for youth to learn how to code, she challenged efforts to overly-scaffold their introduction:

I've been going around to the other classrooms and I've been stressing tinkering. You know, the colleague of mine, she wanted to find a lesson on [website] ... And I'm like, no, we don't need to start there with the training. We actually need to let them kind of play around with the code sheet that's on there and see what the Ozobot does with each one of those codes and then have them to actually design and create their own track that the Ozobot can follow using those codes. So I've already trained 11 classrooms in my school, and I have stressed, this is tinkering. That's what you're doing. You were finding out how this works. Um, and even some of the teachers that I have trained have said, I like that word tinkering. It is better than saying we're going to play ... I see the importance of it, you know, because even though it might look like play to some, to somebody else in my school, actually [the students] are learning and they are figuring out how something works. That's what engineering is, you know, it's learning how something works. (Interview 3)

Alma talked about pushing back on a colleague's plan to provide structured activities for students to learn the functionality of the robots. Instead, she advocated for students to be able to work with the materials to see what they could do, positioning them with agency to “design and create”—words from the EDP—their own tasks for the robot to accomplish. Alma drew on the nonlinear nature of engineering to reframe what it means to learn engineering in elementary classrooms—instead of learning how to follow the steps of the EDP, she here positioned it as learning how to “figur[e] out how something works.” This expansion of what it means to teach and learn engineering start to disrupt some of the dominant narratives of control for K-12 students, positioning students with agency to explore their own ideas.

Another way in which she experienced dominant narratives of control was in how little time she was given to teach STEM units, which constrained what she thought she could do pedagogically in her classroom. In several interviews, she brought up that the school district did not provide extended blocks of time that would allow her to implement the kinds of STEM projects she hoped to teach. She even lobbied her local state representative to provide more time for science in elementary classrooms. The time constraints were a major factor in how she planned her lessons. Early in the program, she talked about how she had to fit her engineering projects into a single 45-minute class period, leading students quickly through the steps of the EDP to accomplish their designs. At the end of the program, Alma referenced the nonlinearity of the EDP as an impetus to push back on the time constraints in favor of her students' engineering learning:

Alma: Well I know that I used to think that the engineering design process was linear, you go straight across. I have since found out that it's a little bit ... Let me draw it. The engineering design process looks more like this (holds up paper showing pen scribbles).

Interviewer: It's scribbles.

Alma: All over the place. I've actually learned I need to give my kids a little bit more time. I can't push them as fast as I'd like to if I want to really get a really good product out of them. So I kind of learned how if it takes more than one class period, that's okay. We'll do it in 10 days or we'll do it in two and a half days, because I really want to give them more time to improve, than I've done in the past If I stop with this project right now, is it really benefiting them? Have they really learned anything? So, yes, I think that's really changed my mindset quite a bit ... (Interview 6)

Drawing on her appropriation of the EDP, Alma created a visual to describe how she saw its nonlinear nature. She drew on this idea as a tool for her pedagogical reflection. Recognizing the need for students to have time to navigate the different steps of the design process, she became much more flexible in how she planned her engineering projects: if a project runs over its allotted time, Alma talked about the need to shift how she plans her classes to allow students more time. I argue that this is a disruptive beginning in resisting dominant narratives and structural constraints that control the content to be taught and how teachers and students participate in learning. Instead of marching students through each of the steps in a single class period, Alma talked about using class time to support students to really think through their designs, how to improve them, and what to learn from them. Instead of giving them "five to ten minutes" to plan, she talked about letting students plan for a whole class period, finding that students provided "a lot more details, [had] a lot more written down where they had really talked out and thought about it" than when given less time. Appropriating the EDP again gave her space to position both herself and her students with greater agency to push back on the ways time and scheduling limited their work together.

Discussion

Connecting disciplinary engagement to dominant narratives

Given the critical role that teachers can play in either reinforcing or challenging dominant narratives, it is important to understand what resources support them to reimagine these disciplines in K-12 schools. As prior work has shown (Varelas et al., 2005; Windschitl, 2003), helping teachers to shift their own participation in disciplinary activities will only get us so far. Teachers may authentically take up disciplinary tools in their professional learning but use these tools in ways that perpetuate dominant narratives that restrict who their students can be in school and in STEM disciplines (De Lucca et al., under review). Instead, Alma's case motivates making more explicit the links between teachers' disciplinary engagement and the narratives that shape their and their students' places in the discipline. In my analysis, I connect how Alma takes up the discourse of the engineering design process to her tacit challenges of restrictive disciplinary narratives. While she may not have been aware of the gendered, classed, and racialized histories of engineering, I argue that her appropriation of the EDP still serves to expand what counts as engineering to include her and her family's work as loom technicians, supervisors, garage builder, construction workers, and textile designers.

In addition to challenging what counts as STEM, Alma drew on her appropriation of the EDP to contest dominant narratives of K-12 schooling, in particular, narratives of control in which elementary students (and teachers) need to be led through class activities. Notably, she did not just ignore the school narratives. Instead she appropriated specific words and phrases associated with the EDP—tinkering, not linear—to make space for new ways of conceptualizing the work of teaching engineering within her institution. She also drew on her appropriation of the EDP to notice and value more of students' thinking in engineering, shifting from assessing which step students were on to noticing the rich and diverse design practices that the EDP represents in professional engineering.

At the same time, the flipside of Alma's case is how disciplinary tools can be used to further reinforce dominant narratives of engineering, STEM, and school. One dominant narrative in K-12 schooling in the U. S. centers on "custody and control" (Golann, 2015; Noguera, 1995), emphasizing the need to script students' moves and plan what they are allowed to say or do in any given moment. These narratives extend to include the need to control teachers' work (D'Amico Pawlewicz, 2020), which is evident in policies that limit the time and agency of teachers for teaching. The straightforward, step-by-step representations of the EDP, just as mathematical problem-solving steps (Schoenfeld, 1988), the scientific method (Tang et al., 2010), and scripted writing algorithms (Brannon et al., 2008), can serve to reinforce these narratives, dictating what students are permitted to do and when they are permitted to do it. Under the guise of learning engineering practice, this approach has the potential to simply be another way to restrict students' agency, funneling them and their ideas through a process that actually bears little resemblance to the creative, iterative, messy process of engineering design. Therefore, there is a need to consider how disciplinary tools, whether from STEM professional communities, from STEM education initiatives, or from informal STEM spaces, can be drawn on and transformed for more liberatory ends in K-12 schools, rather than to reproduce the educational norms and practices that limit what students can do.

Considerations for teacher education

There has been extensive scholarship examining how to support educators to develop critical perspectives (Carter Andrews et al., 2019; Gay & Kirkland, 2003; Kumashiro, 2004; Ladson-Billings, 2009), including in STEM education (Mensah & Jackson, 2018; Morales-Doyle et al., 2020; Sengupta-Irving et al., 2021; Tan et al., 2021). Alma's case contributes to this body of work by highlighting the potential of teachers' disciplinary engagement as another lever for helping teachers to become more critical educators.

While learning scientists have distinguished between *learning of* disciplines and *learning for* engaging in the disciplines (Russ, 2014; Wendell et al., 2019), I propose there is a need to consider *learning to navigate and challenge* dominant narratives of the disciplines and school as a central goal for teachers' disciplinary engagement. Learning to navigate and challenge dominant narratives would involve teachers making connections, as Alma tacitly did, from the disciplinary ways of knowing, engaging, and communicating in their professional learning to the broader narratives about STEM activities and who participates in them. It involves negotiating not just moment-to-moment interpretations of particular disciplinary tasks, but also interpretations of histories and futures in the disciplines, particularly the sociopolitical aspects of these interpretations. Importantly, Alma's case emphasizes the need for this navigation to be personal, so that teachers are positioned with agency to transform disciplinary tools in ways that are powerful for them and for their students.

Alma's case has impacted my teaching and scholarship with science and engineering teachers. While engaging teachers and teacher candidates in disciplinary activities continues to be a central component to my work in supporting them to foster meaningful forms of science and engineering in their classrooms, I now integrate explicit conversations about how teachers' disciplinary engagement can challenge dominant narratives that shape how the disciplines are portrayed and taught in schools. For instance, in science we reflect on how aspects of our disciplinary engagement might not be recognized in schools, such as use of analogies (Brown, 2021), perspective taking (Warren, et al., 2001), or storytelling (Marin & Bang, 2015). We consider how narrow visions of what counts as the engineering design process or scientific method disproportionately impact marginalized populations (Brown, 2021; Bang et al., 2012), and how the heterogeneity in our own engagement can make space for us to see more productive resources for doing science with students. In pre-service teacher

education, I have found that these conversations create space for teacher candidates to make connections across their (discipline-general) social foundations or classroom ecology courses. By creating opportunities to connect their learning in these courses with their disciplinary activities, teacher candidates can ground their emerging reflections on equity and justice within their expanding understandings of the disciplines they (seek to) teach. Below I unpack additional considerations for teacher educators to strengthen the connections between teachers' disciplinary engagement and their development of more critical perspectives.

Making sense of personal histories & connections to disciplines

First, Alma's case motivates thinking about how to provide opportunities for teachers to make sense of their own experiences and histories within their professional learning communities. Others have argued the need for professional learning to engage with teachers' histories and positionalities in STEM, making that an explicit aspect of the design of professional learning communities (Mensah, 2019; Wright et al., 2020). For instance, Wright et al. (2020) documents how a teacher's racialized and gendered positionalities can impact how they participate in a professional learning community for teaching engineering. His work highlights the need to design these settings in ways that help teachers recognize themselves and their students in engineering, particularly those who are from and teach students from marginalized communities. Importantly, this work emphasizes the need to consider how culture and power are a part of this recognition work, to acknowledge that while all teachers bring their own diverse perspectives, histories, and approaches to engineering, what is seen as valuable and worthy of recognition is shaped by dominant narratives in engineering and in school. Therefore, in addition to making space for engaging with one's own personal histories, teachers need to develop a critical awareness of these narratives to make sense of these histories. To support teachers to develop this awareness, teacher educators might offer space for teachers to reflect on how their engagement in disciplinary activities in professional development or education courses differs from their prior formal learning experiences, what those differences mean for what and who is recognized as valuable in these disciplines, and how their engagement impacts their identities as scientists, engineers, or mathematicians—and teachers of these subjects. This space for reflection is particularly important for teachers of color who have been marginalized in STEM learning spaces (Mensah & Jackson, 2018).

Developing critical awareness of dominant narratives & intersections with disciplinary activities

Most of Alma's challenges to dominant narratives in engineering and in school were in response to her personal stories and experiences, which primarily focused on aspects of class and ability. While she engaged with the narratives that personally affect her and her family, she was less attentive to how race and gender (and their intersections with class and ability) might be implicated in what counts as STEM and who is seen as an engineer. Her case therefore motivates considering how to support teachers to recognize the varied ways that dominant narratives can oppress others in disciplinary learning, beyond their personal experiences. This approach would require developing teachers' political clarity to recognize the racialized, classed, gendered, and other powered ways that "students' forms of knowledge and ways of being are positioned in society, schools, science classrooms, and the domains of science, as well as students' interests and resources for achieving in those domains and related career pathways" (Madkins & McKinney de Royston, 2019, p. 1325).

Critical teacher educators have made this aspect of teachers' learning an explicit goal in their work with STEM teachers, emphasizing the political nature of disciplinary teaching and learning (Gutiérrez, 2013; Mensah & Jackson, 2018; Morales-Doyle et al., 2020; Mutegi et al., 2022).

Thinking about this work in light of Alma's case raises questions about how to engage teachers to navigate their disciplinary engagement with more critical awareness, to coordinate their framing of their disciplinary activities with more critical perspectives on narratives of STEM and school. Therefore, teacher educators might supplement disciplinary activities with readings or community resources that highlight epistemic diversity and the role of historicity and identity in addressing disciplinary problems (Agarwal & Sengupta-Irving, 2019). For instance, teachers' investigations of the water cycle might consider other ways of knowing about water (e.g., Blackstock, 2001) and the political history of the (mis)use and restriction of water from nondominant communities (Davis and Schaeffer, 2019). Making deeper connections to issues of equity and justice should be a central goal in designing for teachers' disciplinary engagement, rather than siloing these concerns to other courses or programs.

Curating disciplinary tools for their sociopolitical possibilities

Lastly, I suggest that this case also motivates thinking strategically about which disciplinary tools to highlight in teachers' activities to consider their affordances for reframing their teaching and disrupting dominant narratives. For Alma, she drew on the heterogeneity and dynamic nature of design to appropriate the EDP and challenge narrow conceptualizations of who is seen as an engineer and what it means to learn engineering. Other disciplinary tools might offer different affordances: for instance, the relational and cooperative perspectives in ecology could be used to challenge individualistic perspectives not just about nature, but also about learning in school science (Hecht & Crowley, 2020). Biologist Beronda Montgomery (2020) considered how scientists' approaches to studying unculturable bacteria could inform approaches to inequity in science learning. Just as microbiologists consider organisms' unique languages and communities, seek to replicate the environments in which these organisms have thrived, and recognize organisms' needs to transform environments to survive, science mentors (and educators) can shift their approach from solely expecting individuals to thrive in hostile environments to identifying and replicating features of environments in which marginalized students succeed.

This approach invites us to consider which disciplinary tools and practices to emphasize not just because they are what practitioners use or engage with, but in terms of how they can serve to enact change at a broader level, in challenging what (and who) counts in STEM and school. It recognizes that the selection of which aspects of disciplinary practice to emphasize is already and always curated and political (Dyches & Boyd, 2017). Indeed, narrow definitions of engineering in K-12 education as the application of math and science to real-world problems can be traced in the history of the professionalization of the discipline which served to benefit the interests of the white, male, upper-middle class (Oldenziel, 1999; Pawley, 2009; Slaton, 2010). This perspective builds on challenges to the "settled expectations" (Bang et al., 2012), reconsidering which disciplinary practices need to be emphasized in engineering (and STEM) teacher education. Of course, at the same time, disciplines will only get us so far in bringing about equity and justice.⁴ Therefore, I see it as critical to think expansively, not just about the disciplines we teach, but also about the scales, mechanisms, relationships, and geographies of learning to challenge oppressive structures and narratives. Alma's story portrays one avenue in a necessarily complex terrain for creating more equitable and just learning environments.

⁴I have been reflecting on the work of Katherine McKittrick to consider this point: "Disciplines stack and bifurcate seemingly disconnected categories and geographies: disciplines differentiate, split, and create fictive distances between us ... Discipline is empire." (McKittrick, 2021, p. 37).

Conclusions

In my analysis, I sought to learn from Alma's stories, how she connected to her history and to her present time, how she has bridged the personal, political, and disciplinary in reflecting on her learning in TEEP. I drew on the constructs of appropriation and framing as a way to weave together these different aspects of Alma's stories, both from her professional learning and from her personal reflections. Her voice highlights, for me, the need to rethink how to position disciplinary engagement and tools for teachers, seeing them as useful to learn not just about the disciplines or how to engage in disciplinary activities, but how to navigate and trouble the different narratives of STEM and school. Moreover, Alma's stories emphasize the need for supporting teachers to not just take up new disciplinary or pedagogical tools that researchers identify as important, but to transform them to better address the needs, desires, and stories for themselves and their students.

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