Centering Relationships in STEM Disciplines: A Sociopolitical Lens on Teacher Learning

Brian Gravel, Tufts University, brian.gravel@tufts.edu
Eli Tucker-Raymond, Boston University, etuckerr@bu.edu
Maria Olivares, Boston University, mariaco@bu.edu
Amon Millner, Olin College, amon.millner@olin.edu
Christopher G. Wright, Drexel University, cgw57@drexel.edu
Jessica Cellitti, Voyager Community School, jess@voyagercommunityschool.org
Rasheda Likely, Drexel University, rsl67@drexel.edu
Mikhail Miller, Drexel University, mm4879@drexel.edu
Jessica Watkins, Vanderbilt University, jessica.watkins@vanderbilt.edu
Jennifer Radoff, University of Maryland, College Park, jennifer.radoff@gmail.com
Erin Ronayne Sohr, University of Maryland, College Park, esohr@umd.edu
Ayush Gupta, University of Maryland, College Park, ayush@umd.edu
Maxine McKinney de Royston (discussant), University of Wisconsin-Madison, mckinneydero@wisc.edu

Abstract: Teachers' own interactions and identities in STEM disciplinary spaces can shape the opportunities that they provide for their students. This symposium brings a sociopolitical lens to examine the relational aspects of teachers' learning. Attending to the ways power and privilege intersect with teachers' relationships to STEM, the four papers highlight the role that race, class, and gender play in how teachers position themselves, are positioned, and are recognized by others in STEM. Across diverse in-service teacher education contexts, this collection contributes rich examples that characterize the powered and politicized nature of teachers' relationships to STEM, examine how these relationships evolved over time, and reveal implications of these relationships for teaching. The symposium raises critical questions on how to support teachers in developing disciplinary relationships that foreground the politicized nature of teaching and learning STEM.

Overview

Teaching and learning, including in STEM fields, are political acts (Apple, 1979; Bartolome, 1994; Darder, 2002; Freire, 1973; 2005; Gutiérrez, R., 2012; Moses & Cobb, 2001; Ladson Billings & Tate, 2001). Recognizing this, learning scientists have taken a sociopolitical lens to examine the powered and relational aspects of STEM learning environments (Digiacomo & Gutiérrez, K., 2016; Lee, 2010; Nasir, 2011; Engle, Langer-Osuna, & McKinney de Royston, 2014; Vakil & McKinney de Royston 2019; Sengupta-Irving & Vossoughi, 2018; Vossoughi, Hooper, Escudé, 2016). This literature attends to the ways that power and privilege shape how interactions unfold, knowledge is produced, and identities are constructed (Esmonde & Booker, 2016). Much of this prior work in the learning sciences has foregrounded students in the constellation of relationships within STEM learning environments, highlighting how students position themselves, are positioned, and are recognized by others within STEM disciplines in racialized, gendered, and classed ways (Brickhouse, 1994; Brown, 2006; Calabrese Barton & Tan, 2018; Martin, 2000; Nasir, 2011). In this symposium, we center *teachers' relationships to STEM disciplines* to examine the politicized nature of teachers' interactions with others and the development of their disciplinary identities.

In focusing on teachers' relationships, we broadly examine the social exchanges that shape how people understand their roles and obligations as well as their expectations of others' roles and obligations (Bryk & Schneider, 2002). These social exchanges, taking place in particular moments and over time, can be with people, including teachers, students, and members of the local community, as well as with aspects of the discipline, such as disciplinary practices, epistemologies, and products. Prior research on the relational aspects of teachers' learning in STEM has focused on their development of dominant disciplinary practices and identities (Luehmann, 2007; Varelas, House, & Wenzel, 2005), often in depoliticized ways. Drawing on work that has argued for the need to develop teachers' political knowledge for STEM teaching (Gutiérrez, R., 2018; Ladson-Billings, 1995; Paris, 2012; Warren & Rosebery, 2011), this collection of papers foregrounds the political dimensions in developing teachers' disciplinary relationships and identities. Across diverse in-service teacher programs, these papers examine how power, race, gender, and class shape teachers' social exchanges with other teachers, students, and researchers, as well as with the disciplines they teach.

Notably, we center teachers' relationships in our work not just as a means to achieve an end, that is, not just to help teachers develop new pedagogical reasoning or practices. Instead, we see these relationships as critical objectives themselves for teachers' professional learning. This set of studies amplifies the need for "politicized care" (McKinney de Royston, et al., 2017) not just for students, but also for teachers in STEM disciplinary spaces, particularly those who have been marginalized in STEM and schooling (Mensah, 2019) and for those teaching students from marginalized populations. We position teachers' developing more equitable and just relationships with the discipline and students as central to enacting sociopolitical and disciplinary change.

Paper 1 explores the ways in which teachers renegotiate relationships to disciplines, tools, and students through a professional learning opportunity that integrated computational making into STEM disciplinary classrooms. Paper 2 examines how an approach of purposeful identity construction supported the racialized disciplinary identities for African American elementary school teachers of engineering. Paper 3 examines how teachers developed new disciplinary relationships, made connections between these relationships to their lives outside of school, and drew on their relationships to contest cultural narratives around class and ability in school and in their everyday lives. Paper 4 explores one teacher's efforts to integrate science and social studies in ways that center the political dimensions of socioscientific issues. Notably, this set of studies explores teachers' relationships in the context of STEM areas that do not have the extensive history that mathematics and science do in K-12 schools—computational making, engineering design, socioscientific issues. These studies show the possibilities of these new curricular spaces for renegotiating teachers' relationships in STEM contexts.

The symposium will start with introductory remarks that situate this collection of papers in light of ongoing sociopolitical work in the learning sciences, teacher education, and STEM education. Instead of audience questions during transition time, we will invite audience members to discuss with each other and "peer review" their questions (Tuck, 2019) for later discussion. Maxine McKinney de Royston will provide synthesis and critique, addressing the political, theoretical, and methodological clarity in the collection of work. She will also facilitate the remaining time for audience questions and discussion.

Re-Making STEM through computational making and critical relationality

Brian Gravel, Eli Tucker-Raymond, Maria Olivares and Amon Millner

This paper highlights the roles of computational making and critical relationality in helping teachers reorient to their students, the disciplines they teach, and the tools with which they use to teach those disciplines. *Computational making* is a constellation of practices involved in creating artifacts that combines elements of computational thinking (Lee et al., 2011; Wing, 2006) with making practices (Tucker-Raymond & Gravel, 2019; Peppler, Halverson, & Kafai, 2016). Computational making practices include: decomposing problems; brainstorming with materials; attending to precision; abstracting and modeling; selecting tools, materials, and procedures; and iterating design (Gravel et al., forthcoming). *Critical relationality* (Olivares et al., 2019) foregrounds people's relationships with others as resources for participation in learning (Antrop Gonzalez & De Jesus, 2006; Rosebery, Warren, & Tucker-Raymond, 2016; Duncan Andrade, 2009; Sandoval, 2013). It centers the ways in which agency, structure, and connections to others mediate learning (Bartolome, 1994). Critical relationality reflects a commitment to examine and disrupt pedagogies that oppress students of color through disregard for their experiential and out-of-school knowledge, and the denial of their epistemic rights and humanity. Relational learning settings can transform opportunities for youth of color in STEM (DiGiacomo & Gutiérrez, K., 2016) when those spaces are connected to the social ecologies of their lived selves.

We designed a 12-month teacher professional learning opportunity (PLO) where K-12 math, science, and technology teachers a) explored computational making on their own through craft, electronic, and digital materials, b) entered into co-making, co-learning arrangements with students, and c) designed and implemented units for their classrooms. Seventeen teachers participated across two school districts for roughly 75 hours of professional learning and planning, followed by individual classroom implementations that varied from 5 days to 12 weeks. Through this work, we asked: In what ways does participation in the professional learning model contribute to changes in teachers' relationships to tools, disciplines, and the students they teach?

We use case study methodology, appropriate for in-depth study of a small number of instances of a phenomenon (Goetz & LeCompte, 1984), to illuminate the dynamics of shifts in teacher beliefs and practices. Case study methodologies complicate what might seem to be straightforward contexts by striving to document and understand local particulars through a broader interpretive context—how the choices of one context are among a universe of possibilities and what impact they have on the subjects of those cases (Dyson & Genishi, 2005). Using data from across the professional learning design, including video of teachers and students at work, interviews, and fieldnotes, we used constant comparative analysis approaches (Charmaz, 2014) to identify the ways in which teachers changed their relationships to their students, their disciplines, and the tools of their

disciplines. We present two cases to illuminate the dynamics of shifting relationships. In case studies 1 and 2, 50% and 60% of students, respectively, were from racial/ethnic groups underrepresented in STEM.

Case one highlights the ways in which, Denise, an 8th grade science teacher connected her own learning in science, along with that of her students, to social movements. Denise's participation in the PLO drove her to wonder about *"big picture connections"* and the ways in which they connected to specific scientific understanding of the laws of motion. Denise wanted to develop a unit *"as a way to hook some of the students who know science may not be their thing."* Focusing on current events, and *"the issues they talk about,"* that she overheard them discussing as they walked in her room, she arrived at asking her students to construct kinetic sculptures that would address one of Newton's Laws of Motion to express their ideas about social movements, such as Black Lives Matter. In this, she transformed her role and her relationship to the students, *"I don't necessarily have to have an idea for everything cause like the kids are creative…. But it's just good practice for me to go through it myself so I can help them better if I have wrestled with the same problems that they might come up against."* Denise became an authority broker, collapsing traditional authority structures and redefining what was relevant, how students could participate in science, and how they were supported. This reformed relationship to her students and to science teaching opened space for some students to center their racialized identities (Nasir, 2011) in the context of science class. Among other social movements (e.g., climate change, me too, no border/no wall), three groups of students in the focal class used the Black Lives Matter movement to contextualize their explorations into the laws of motion. In one group, the participants, who all identified as Black, used their project to express complex relationships between skin tone, identity, and racialized interactions in the world at the same time that they explored action/reaction; with one student saying, *"we all know that science relates to life and things like that and what we see around us every day but this was like a different way to put the two together, like science and social movements."* Focusing on issues students cared about allowed Denise and her students to disrupt the ways in which racial identities often play out in science class (Emdin, 2011) and the ways in which computational making, through attention to precision, iteration, brainstorming with materials, and modeling could be integrated into an inquiry-based science classroom. Case two highlights the ways in which Haley, an experienced 8th grade mathematics teacher who, through her co-learning with students, reoriented her thinking about math and making. Due to space constraints, we do not elaborate here, but we will share these findings in the symposium session.

Integrating computational practices into math and science classrooms is difficult (Yadav, Krist, Good & Caeli, 2018), especially when teachers have little experience. Computational making served as the integrative tool and critical relationality as the ethical guidestar for helping teachers reconsider relationships with students. The PLO supported teachers in repositioning themselves as learners alongside their students, where new agentive pathways for students were opened through the shared learning experiences and redistributed authority over tools, ideas, and problem spaces, particularly with attention to students of color. This work has implications for how we understand the transformative possibilities of computational approaches to STEM teaching and learning, paying particular attention to teachers' relationships to students, disciplines, and tools, through a critically informed inclusion of the experiences of students of color.

Incorporating racialized recognition work in the design of teacher learning

Christopher G. Wright, Jessica Cellitti, Rasheda Likely, and Mihkail Miller

In accordance with K-12 education in general, engineering education has a teacher diversity problem. Diaz, Cox, and Adams (2013) assert that "similar to efforts in engineering to increase the representation of underrepresented groups in science and engineering careers, efforts to increase the representation of minority teachers with interests in design, engineering, and technology (DET) are needed in elementary schools" (p. 19). Despite this argument and an increase in research that acknowledges the needs and experiences of Black teachers within spaces of professional learning (Farinde-Wu & Griffen, 2019; Mensah, 2019), this line of research remains under-examined within the engineering education community. Typical approaches to designing teacher experiences have primarily focused on increasing their pedagogical content knowledge and understandings of engineering (Duncan, Diefes-Dux, & Gentry, 2011), as well as refining their attitudes towards the discipline (Perkins Coppola, 2019). In this paper, we contend, in accordance with Mensah (2016), that additional "research is needed about how to integrate the experiences, beliefs, and cultural awareness" (p. 50) of Black teachers within spaces of professional learning in engineering.

Foregrounding engineering teacher preparation through a lens of identity development, we focused on the availability of identity resources for two Black female elementary teachers' construction of identities as teachers of engineering. Conceptualizing an identity of a teacher of engineering as being recognized by self and others as displaying competencies for the teaching and learning of engineering (Lottero-Perdue, 2013), we highlighted the notion of what it meant to be *recognized* as a Black teacher of engineering who teaches engineering

to a predominantly Black student population. Here, our approach acknowledged that processes of recognition are informed by disciplinary understandings of what it means to teach engineering, and could also be informed by socially and historically constructed deficit conceptions of race, class, culture, gender, and/or language.

Utilizing case study methodologies, we reflected on how identities as teachers of engineering were specifically made available to the two Black female teachers and analyzed the ways in which these teachers take up identity resources during learning activities. In order to identify identity resources made available to participating teachers, we depended on video recordings and transcripts from research team meetings where specific processes were designed and consistently refined. Additionally, in order to gain insights into how the teachers took up these resources, we relied on field observations (i.e., PLC sessions and the facilitation of engineering lessons), semi-structured interviews, and formal and informal conversations during or after the implementation of engineering design lessons. The data analysis process was iterative, as the research team reviewed video recordings and transcripts from classroom implementation and PLC sessions on an ongoing basis. Analysis of video recordings and transcripts looked to call attention to identity resources made available in professional learning experiences and relied on Nasir and Cooks' (2009) conceptualization of relational, material, and ideational resources.

Findings discuss the ways in which the learning context incorporated various identity resources in order to attend to issues of racialized disciplinary identity and learning for the two teachers. Analyses revealed how a "purposeful identity construction" approach (Nasir, 2012) that included access to relational, ideational, and material resources simultaneously attended to teachers' racialized and disciplinary perceptions of teaching engineering. Teachers acknowledged that their access to: (a) the disruption of traditional power dynamics in the practitioner-researcher relationship, (b) Black engineering experts, and (c) opportunities for reflection and recognition of their roles as Black teachers within the engineering education community were emergent themes in strengthening their connection to the domain of teaching engineering. Implications for this research highlight the need for both acknowledging and attending to potential issues of power within spaces of teacher learning. Specifically, this recognition work challenges teachers and teacher educators to unpack the ways in which interpretation and recognition are powered constructs due to settled expectations (Bang et al., 2012) of participation in both school and the discipline of engineering.

Teachers' developing humanizing relationships to engineering

Jessica Watkins

In this paper I explore how two teachers develop humanizing relationships to engineering in in-service teacher education program. I build on emerging scholarship that advocates for teacher education to both affirm and sustain teachers' whole selves, while also developing their critical consciousness to recognize and disrupt systems of oppression (Bartolome, 1994; Carter-Andrews, et al., 2019; del Carmen Salazar, 2013). I examine how teachers' relationships to STEM disciplines, specifically engineering design, can be sites for supporting teachers' *becoming* (Friere, 1970) in and out of the classroom. Drawing on the framework from Sawtelle and Turpen (2016), I conceptualize teachers' relationships to engineering as involving three interacting components: *epistemology*—how they describe and enact ways of knowing and learning in engineering (Wendell, Swenson, & Dalvi, 2019); *identity*—how they position themselves and are positioned within engineering practice (Holland, Lachiocotte, Skinner, & Cain, 2001); and *affect*—how they navigate emotions in engineering as discursive practices (Chubbuck & Zembylas, 2008). To examine how these relationships can be humanizing for teachers, I consider both (1) how teachers make connections between their disciplinary relationships and their lives outside of the program and schools and (2) how these connections have the potential for liberatory outcomes, that is, to contest cultural narratives around class, gender, race, and/or ability.

This study takes place in the context of an online asynchronous program in which teachers take four graduate courses over eighteen months, including two courses on the content of engineering design and two courses on engineering pedagogy. Teachers were interviewed six times: at the start and end of the program, and after each course, and their coursework was collected. I analyze two cases (Merriam, 1988) illustrating possibilities for teachers' developing humanizing relationships to engineering. Alma is a veteran 3rd-5th grade science teacher in a rural, racially-diverse public school in southeastern US. Margaret is a veteran 3rd grade science and math teacher in a religious, racially- and socio-economically diverse school in northeastern US. I first looked at their interview transcripts, selecting excerpts in which teachers talked about their perspectives on engineering and connections to their lives. From these excerpts, I constructed claims about teachers' disciplinary relationships, refining through peer debrief and triangulation with teachers' coursework. Comparing these cases, I developed themes characterizing their relationships to engineering and connections to their lives (Table 1).

Table 1: Characterizing Alma's and Margaret's developing humanizing relationships to engineering

Teacher	Developing relationships to engineering	Making connections to other aspects of their lives	How these connections have the potential for liberatory outcomes
Alma	Takes up heterogeneity in engineering to position herself in the discipline	Connects to her and her family's history as factory workers, labeling their work as "STEM"	Takes up the "STEM" label to push back against class-based hierarchies for what counts as engineering in and out of school
Marge	Takes up idea generation & iteration in design thinking to position herself as part of a collective, iterative process	Connects to her personal interactions, describing how she started sharing her ideas even if unsure they would work, so that co-workers & family can make better collective decisions	Takes up idea generation as a way to position herself and students as contributors, potentially challenging individualistic and gendered interaction patterns

In one case, Alma joined the program with some prior experience teaching engineering units in her classroom. At the start of the program, Alma tended to narrowly focus on the steps of the design process, equating "engineering" with "building." As she started to learn more about the diversity in engineering, including both the different ways of thinking and technical jobs that engineers engage in, she began to see more of herself in the discipline, for instance as a "systems thinker": "*I didn't realize there were that many types of engineers…. I wouldn't have ever imagined I would have been classified as an engineer, but now I see it."* (Interview 4). Alma's developing relationship with engineering involved her expanding epistemological understandings, which allowed her to position herself within the discipline and express confidence in her role. In doing so, she also made connections to her family's history as factory workers: *"I have come to the realization that my family and I were actually manufacturing engineers of blankets…. We had to each have some mechanical engineering knowledge to understand how to repair a sudden stop of one of the looms we were working with*." (Course 3, Week 2 reflection). In addition to making sense of her past, she also took up the label of STEM to push back on narrow traditional academic outcomes and to reimagine her son's and others' futures: *"[The educational system] needs to be fixed for these kids so that they can have these opportunities… my son is not an academic student, and he's never going to be. But you get him to manipulate and build something and create it, he can do it… That is still STEM.*" (Interview 5). Her relationship allowed her to contest what counts as STEM both in and out of the classroom.

These analyses contribute to ongoing conversations exploring the interrelated nature of teachers' epistemology, affect, and identity, showing how expanding epistemological understandings can make room for teachers to develop new ways to experience and identify with STEM disciplines. Furthermore, we show that these expanded relationships provide opportunities for teachers' disruption of cultural narratives that limit their and their students' recognition and development of their whole selves.

Repoliticizing the classroom: A case of creative insubordination

Jennifer Radoff, Erin Ronayne Sohr, and Ayush Gupta

Despite many calls in education to recognize the political nature of teaching and learning (Gutiérrez, R., 2018; Philip, Bang, & Jackson, 2018; Vakil, 2018), many academic and educational institutions continue to participate in denying and delegitimizing the political dimensions and implications of disciplinary learning. This happens, in part, through institutional constraints like the siloing of academic disciplines and the "whitewashing" or sanitizing of politically-divisive curricular content (Sandoval et al., 2016). These artificial divisions between disciplinary content and politics have become so naturalized that many do not think to question the lack of sociopolitical discourse in a science classroom, for instance. These divisions, however, are not natural. They serve to reify the political interests of those with power under the guise of preserving "objectivity," while at the same time delegitimizing counter-narratives as "subjective" and "biased." Contesting depoliticization is challenging, in part, because what happens in classrooms is constrained by policies, standards, and practices that preserve the status quo with respect to power. Teachers who question the "hidden curriculum" (Apple, 2004; Giroux, 1983) must do so carefully, through a process of complex negotiation of the various conditions that they are working with and through. Rochelle Gutiérrez describes this work as "creative insubordination," which "recognizes innovative work that individuals, in collaboration with others, do when they need to get a job done but when doing so will be met with resistance from those protecting the status quo" (Gutiérrez, R., 2018, p. 22). In this paper, we share a story of creative insubordination. We show how Lagertha, a fourth-grade science and social studies teacher, worked to challenge depoliticization in her classroom, and we explore some of the factors that enabled and constrained her evolving sense of what was possible to do in her classroom.

Lagertha was one of seven elementary teachers working together with two university researchers in a research-practice partnership focused on collaborative inquiry into socioscientific and sociopolitical issues. We collected video and audio records of project meetings, which were content logged and transcribed by a member of the university research team. Early in the partnership, when the group was discussing what kinds of projects to take on, Lagertha shared an experience from a professional development workshop she recently attended about animal migration, hosted by a local Environmental Research Center (ERC). The ERC facilitators immediately established that participants were "NOT allowed to talk about immigration, like, what's happening in America right now, politics, or any opinions that you have about it," which was rooted in a long-standing history and culture of maintaining strict divisions between science and politics in academic spaces. Rather than deter Lagertha, the workshop had the opposite effect: All she could think of were parallelisms between animal and human migration and the opportunities for studying them together in an integrated science and social studies unit.

For most teachers, an integrated unit would be a practical impossibility due to institutional practices that limit teachers' autonomy and promote the siloing of academic disciplines. But Lagertha, who was a tenured, well-respected teacher in her school with minimal administrative oversight, saw this as an opportunity to maximize class time by highlighting the rich connections at the intersection of these issues. Working within her own institutional and local conditions, Lagertha built an integrated unit that elevated traditional science content on animal migration with deeply consequential issues of immigration:

> I thought that these [science] questions have a translation to the human migration, it's the same- What triggers humans to migrate? Why? How do they get here how do they prepare, what's in their suitcase...Um, and then the challenges. I mean, that in itself, is another inquiry, like how do you face the racism of like the people that's receiving you. Or the [current US] border situation.

While the school-mandated curriculum and textbook effectively reduced US immigration to an apolitical celebration of White, European colonialism, it was important to Lagertha to study its complex political history and to acknowledge the violence and racism that many immigrant communities face. Doing this work, however, meant acting in direct opposition to the school's explicit and tacit framing around how and for whom immigration should be taught. Lagertha's acts of creative insubordination provide a rich and powerful context for understanding the complex navigational, intellectual, and emotional labor teachers engage in when working to challenge depoliticization in their classrooms. Her story should impress upon all of us in the learning sciences community, the responsibility we have to support teachers in this difficult work.

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