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# Work In Progress: Recognizing Empathy as Critical to Engineering: Teacher Reflections in an Engineering Research Experience

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# Recognizing Empathy as Critical to Engineering: Exploring Teacher Reflections in an Engineering Research Experience (Work in Progress)

Recent work in postsecondary engineering education has emphasized empathy as a critical construct related to the development of engineers [1-5]. As scientists and engineers engage in their work, they must consider how they will communicate and collaborate as members of interdisciplinary teams, and how their work will address solutions to real world problems across social, environmental, local, and global contexts. However, the connection between empathy and engineering has not always been an obvious one within the field and its emphasis is sometimes overlooked in favor of prioritizing technical, practical, and conceptual skills [4, 6].

Similarly in the K-12 sphere, teachers of science, technology, engineering, and mathematics (STEM) disciplines have the complex responsibility to translate the content, practices, and understandings of the nature of STEM and the STEM community to their students. However, many K-12 STEM teachers have not had firsthand experiences with STEM-related research beyond undergraduate or teacher preparation programs [7-9] making it potentially difficult for them to fully grasp and incorporate such understandings into their teaching. Moreover, the notion of empathy as a significant aspect of STEM may be easily overlooked by K-12 teachers, in the same way it has been historically overlooked in postsecondary engineering education, if teachers are not attuned to the role and importance of empathy in STEM disciplines [4, 10].

To address some of these concerns, Research Experiences for Teachers (RET) programs have been instituted at many universities and national laboratories to engage K-12 teachers in immersive firsthand participation in scientific research within a STEM community of practice alongside mentor scientists and engineers [11-12]. While RETs are largely understood to be productive professional development experiences for teachers [11, 13-18], much of the research on RETs has not yet examined the impacts of these programs on whether and how teachers understand empathy as an aspect of the professional work of scientists and engineers. To this end, this present work explores the following research question: **How do STEM teachers participating in a seven-week engineering research experience describe and reflect on their perceptions of the relationship between empathy and the work of engineers?**

## Relevant Literature & Framework

Empathy has been described as many different things—a capacity, a skill, a feeling, a disposition, a cognitive ability, and a process [19]. But even with its wide-ranging definitions, empathy is often understood as taking on the perspective of another in an effort to understand their actions, thoughts, and/or emotions [20]. As such, empathy involves decentering from one's own thoughts and feelings to appreciate the cognitive, emotional, and lived experiences of another [21-23]. Related to STEM fields, empathy has started to gain prominence as a disposition worth cultivating in STEM education and within STEM professions. The work of scientists and engineers has a significant impact on our everyday lives as new knowledge is developed that will inform technologies and solutions for localized and global concerns related to the environment, human health and well-being, and social justice [2]. Complex issues such as tackling climate change, depletion of natural resources, access to clean water, and providing equitable access to health care and related technologies are examples of problems that are both “inescapably social and technical” [5-6, p.123]. To address grand challenges such as these, scientists and engineers require not only conceptual and technical expertise, but also social competencies and awareness that allow for interdisciplinary collaboration, communication, and the ability to connect their work meaningfully to viable solutions for real world problems ([3, 6]. As one of these social competencies, empathy has been recognized as a “requisite skill” for engineers [24, p. 307] because engineers must consider multiple and often diverse perspectives as they take on “ethical and professional responsibilities in engineering situations and make informed judgments in their work, [and therefore] must consider the impact on global, economic, environmental, and societal contexts” [25].

In K-12 contexts and educational research, empathy is already largely understood to be an essential aspect of social and relational work within schools and classrooms. Empathy is seen as a critical disposition and dimension of teachers’ work, often in relation to teacher attitudes, student-teacher relational dynamics, and cultural considerations in the classroom [26-30]. Teacher empathy toward students’ experiences has been shown to have important implications for equity in the classroom [30] as teachers can leverage their perspective-taking for students’ cultural and lived experiences to inform their decision-making and enactment of culturally responsive pedagogies or disrupt inequitable power dynamics in the classroom [31]. Similarly, in the context of RET programs, research has shown that teachers report increased feelings of empathy toward their students as science learners after RET participation [11, 13], recognizing that their emotional and cognitive experiences of attempting to learn new content, practices, and skills that are often foreign to them may likely mirror the experiences of their students when they are learning new material in the classroom.

From a content-focused standpoint, however, empathy is not an idea that is typically emphasized as an important disciplinary aspect of STEM that intersects with the work of engineers and scientists. Because disciplinary curricula often prioritize content knowledge, STEM teachers may not fully understand or explicitly address the connection between empathy and STEM and engineering for their students in their learning experiences. Yet, when teachers do make explicit connections for students between disciplinary STEM work and the disposition of empathy through engagement in the engineering design process or through problem-based learning, this can support students to see the content and practices of STEM as relevant to their own lives, the lives of others, and to the personal, cultural, environmental, and social contexts in which they live [10, 32-35]. Given the importance of empathy across STEM and educational spaces, RET programs have the potential to serve as fruitful contexts in which teachers may see and engage with empathy as an intwined and necessary part of the dispositional work of STEM professionals.

**Summer RET Program Structure**

The specific RET at [Institution] was a 7-week, on-campus summer program when participating teachers were on break from their typical teaching responsibilities. During each week teachers commit 35 hours to the program activities. These activities included workshops (one each week on an engineering topic, teaching/curriculum topic, and hands-on training with sensors and programming) and faculty mentored research in a laboratory at the [Institution]. All faculty mentors were from the College of Engineering but housed in different departments including

Electrical and Computer Engineering, Computer Science, Civil Engineering, Chemical Engineering, and Mechanical Engineering. While the engineering research projects were from across different domains, each project was designed to explore an application of sensing technologies for physiological or environmental monitoring. For the first summer, the specific projects from each discipline included: electrical engineering (measuring biological tissue electrical impedance), mechanical engineering (tracking movement using video data), chemical engineering (measuring polymer dielectric properties), civil engineering (measuring concrete maturity), and computer science (integrating programming into STEM focused activities) were available for participants. For these projects, teachers were given a research question that they pursued an answer for (with scaffolding and guidance from their mentor and research students in the laboratory) which culminated in presenting their research progress at an end of program poster session. This process required teachers to learn about the technical topic from engineering textbooks and academic papers, learn how to use laboratory equipment to collect data, design a study protocol to collect and analyze data, use their data to answer their specific research question, and understand the limits of what they could answer based on their data.

The engineering workshops highlighted various disciplines and career paths in engineering and computer science, aiming to broaden teachers' understanding of the field and complement their research, which focused on a single discipline. The sensors/programming workshops introduced sensors and electronics that teachers could use in their classrooms, demonstrate hands-on activities, and gave teachers opportunities to practice programming to control and report values from sensors. The education/curriculum workshops guided teachers in linking their research to educational standards and exploring resources to help teach engineering content in their classrooms. Each Friday of the program, teachers participated in a peer-share session. During this session they shared three successes from the week, two goals for the following week, and one difficulty they faced. The goal of this activity was to help participants recognize that research naturally involves both success and struggles and reinforce that struggles and frustration are normal parts of learning.

**Participants and Data Analysis**

During the 2024 cycle, seven teachers agreed to participate in this present study. All worked in rural middle schools serving majority-minority student populations. Four were science teachers and three were mathematics teachers. All identified as African American and female, and all were first-time RET participants. The data corpus for this study includes fourteen semi-structured interviews. Each interview was conducted by the author. Two semi-structured interviews were conducted with each participant over the course of the seven weeks of the RET (the first during Weeks 2 and 3 and the second during Week 7 of the program). Interviews typically lasted between 30-45 minutes. Questions were centered around the research focus of the participant; their relationship and interactions with their mentor engineer, cohort partner, and others at the Lab; their understandings about the disciplines of science and engineering; their feelings and experiences of doing research; their ideas about how the experience would inform their classroom practice, and their sensemaking about connections between engineering, STEM, and the real world. Each interview was audio-recorded and transcribed by the author.

Each interview set was batched by participant and read in chronological order, starting with the earliest interview. Taking a constructivist grounded theory approach [36], interview sets were closely examined to note participant ideas about empathy, perspective-taking, or helping others; their descriptions of connections between engineering and solving problems in the real world (such as to their own personal lives or issues related to social justice, environmental justice, or concerns for human health and well-being); their connections between empathy and STEM education; and reflections on the ways in which empathy may be important to the professional considerations of engineers. From there, the data corpus was examined, and themes were developed across all participant interviews.

**Findings**

While the analytical work of this study is still in progress, three primary themes have emerged so far in relation to our research question regarding STEM teachers' connections between empathy and engineering. These include **(1) Engineering impacts the lives of real people; (2) Empathy is multidimensional in engineering; (3) Empathy is important in (STEM) education.** As the research team continues to analyze the data, we offer a flavor of the first theme below in an effort to showcase data exemplars and related inferences.

<u>Engineering Impacts the Lives of Real People</u>
All seven teachers were able to describe ways that their summer research focus or the research foci of their teacher cohorts had the potential to positively impact human health and well-being or the environment. As Teacher Kaitlyn (all names are pseudonyms) shared,

> *My mentor's work—what I'm helping with this summer—he's designing wearable sensors to measure fluid around joints. Swelling can be so painful so imagine if you could wear a sensor and it could help you plan and predict for that. It could help so many people. I'd never thought of engineers as helpers like that before.*

Kaitlyn's association to engineers as helpers and engineering's potential for altruistic impact is echoed by Teacher Holly:

> *My thought is, if I can help just one person, I feel like I've done what I'm meant to do that day. I didn't think that'd be so related to my RET project this summer. It is though – we're making sensors that would implant in the bladder to tell if it's full for people who might be paralyzed or incontinent. I can't believe it but, it's personal for me. My daughter has spina bifida. She's been through a lot—something like this would make a huge difference.*

Even as this link was unanticipated, Holly's personal connection to her summer research work gave her important insight into the ways in which STEM can impact the lives of real people in meaningful ways.

<u>Empathy is Multidimensional in Engineering</u>
Several teachers reflected their emergent understanding that engineers approach their work with empathy not only for the individual people their work will influence or affect (as described in Theme 1), but should also take into account the natural environment; sociopolitical, cultural, and historical impacts of their work; and the structures and systems that may benefit, be upheld, or be disrupted by their work. Teacher Annika, who worked with a materials and civil engineer with expertise in concrete, described her learning in this way:

> *When we drive on roads or use our city infrastructure, I don't think people always think*

*about what* used *to be there in terms of the natural environment or displaced communities. It's an important thing to remember—to empathize in that way.*

She continues:

*My mentor talks all the time about how civil engineers and [city] planners have a huge responsibility to think about the impact of their work and injustices that it could carry out. All the time--about the construction of I-75 and I-85 in Atlanta and how the Black community and their major centers of commerce were displaced—cut off—by the interstate. It's segregation. It was racism, regardless of implicit or explicit. It happened in Chicago with their interstate system, too. It's always on his mind. So, I see engineering now as requiring care for people, but for justice as well. Engineers can do great things, but they have to keep all perspectives in mind beyond just a bottom line or efficiency.*

<u>Empathy is Important in (STEM) Education</u>

Finally, several teachers described their feelings that the relationship between empathy and engineering (and STEM more broadly) should be foregrounded in K-12 classrooms for students. In relation to this, Teacher Bonita shared her reflection to this point:

*A lot of students might think STEM isn't for them because they aren't "smart enough" or they don't see the point outside of making money. But a lot of students genuinely want to do something that makes a difference. They want to be able to do something meaningful. Engineers make a difference and a lot of them do so by creating solutions to problems that affect people deeply in their day-to-day lives. They really care about the work they do, but also the people they help, even if they never meet them. If students knew that part of engineering and STEM, maybe more would feel empowered to want to pursue STEM.*

**Significance of the Work**

The RET program at the focus of this study did not explicitly intend to address connections between empathy and engineering, yet this was a major 'outcome' of teachers' reflections and learning associated with their experiences in RET. This work suggests that RET programs have potential to inform teachers' understandings of empathy as a core aspect of engineering and STEM disciplines. While attention to the connections between empathy and the STEM enterprise is not typically an explicit feature of RET programs, it has been fruitful to examine the *implicit* messages teachers may be receiving about the empathy-and-STEM relationship as part of their research participation. Programmatically, this RET built in weekly opportunities for teachers to reflect on their experiences, research, and learning with other cohort members; carefully selected engineer mentors who had positive relational mentoring track records with undergraduates and graduate students; encouraged mentors and teachers to interact and engage with one another beyond topics of research; and created opportunities for explicit teacher reflection through one-on-one interviews. As such, this work highlights an important implication for researchers and stakeholders in the RET community to provide explicit opportunities for teachers to reflect and connect their research experiences with real-world relevance and notions of care and empathy for the social, environmental, local, and global issues that may be impacted by the research. In this way, teachers may be better positioned translate the connections between empathy and STEM to their students, by developing and implementing STEM learning experiences that support students to see disciplinary work as meaningful, relevant, and 'helpful' to their communities and the world around them.

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