YOUTH AS TEACHER EDUCATORS: SUPPORTING PRESERVICE TEACHERS IN DEVELOPING YOUTH-CENTERED, EQUITY-ORIENTED SCIENCE TEACHING PRACTICES

By

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ABSTRACT

YOUTH AS TEACHER EDUCATORS: SUPPORTING PRESERVICE TEACHERS IN DEVELOPING YOUTH-CENTERED, EQUITY-ORIENTED SCIENCE TEACHING PRACTICES

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In this study, I conducted three separate, but interrelated studies that examine the ways preservice teachers (PSTs) generatively developed youth-centered, equity-oriented pedagogical imaginaries in their methods courses and how they enacted these practice(s) in their field experiences. The purpose of this dissertation is to understand how and in what ways a science methods course can support PSTs in the critical uptake of youth (and community) knowledge(s) and practice(s) and how classroom communities in the field can shift/shape these enactments. In this work, I foreground *youth counternarratives of the culture of power in science* as a critical part of learning to teach of science for PSTs –this study has never been done before.

The first study explores how there is a culture of power in science education, particularly in the ways of knowing, doing and being that are legitimized differently from youth's in-school and out-of-school experiences. This legitimization affects the ways youth feel recognized/positioned and ultimately supported to take-action in their science education. Using *counternarratives of the culture of power in science* as a framework, in this study, I worked with youth from an after school green energy program to co-develop digital multimodal cases of science learning.

In the second study, I examined the ways seventeen PSTs, in their elementary science methods course, were supported in developing youth-centered, equity-oriented imaginaries for teaching science to diverse learners. Using the framework imaginaries as practice, I wanted to

know 1) in what ways do PSTs take up youth knowledge(s) and practice(s) in science/engineering learning and 2) how this up-take inform the development of youth-centered, equity-oriented teaching practice(s) in ways PSTs imagine enacting their future teaching experiences.

In the third study, I followed three preservice elementary science teachers in a six-week engineering teaching experience at Liberty Spanish Immersion School in Great Lakes City, Michigan. Using the framework enactments as practice, I aimed to understand 1) in what ways do preservice elementary science teachers enact youth-centered, equity-oriented teaching practice(s) in an engineering unit focused on teaching engineering design for sustainable communities and 2) how are these enactments shaped by local contentious practice.

Implications for this dissertation study include designing a methods course alongside field experiences in support of critically engaging PSTs with cultural/historical/social community underpinnings of youth in equitably consequential ways.

To my Tita Sonia,
Thank you for teaching me to teach with love

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PREFACE

We must never forget the struggle and remember that it will always take a village.

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KEY TO SYMBOLS AND ABBREVIATIONS

STEM	Science, Technology, Engineering, and Mathematics

CHAPTER ONE:

INTRODUCTION

I begin with Faith's vignette as an example of how one youth[1] merged her cultural, home and community practice(s) with her science learning and why it is important for science teacher education.

Faith, a 14-year old youth who identifies as an "engineer and psychologist," describes her interest in using engineering as one that should help people "feel better about themselves, both physically and emotionally" (Chapter 3, Interview 3). She engineered a FANcy Hat in the after school green club where she participated for over three years. The FANcy Hat is a solar-powered fan hat that helps community members stay cool during the summer time. When identifying problems that the FANcy Hat as a solution would address, she first thought about her Grandmother who attended an un-airconditioned church in Florida. Over time, after seeing the impacts of her design in Faith's community, this idea expanded to include her Grandmothers that attended her local Great Lakes City Baptist Church, her family members (twin brothers and parents) as well as her fellow high school classmates who ran track in the hot, summer Michigan sun.

It was important to Faith that her community members' problems and perspectives become central to her FANcy hat design. For example, during our time together, Faith discussed memories of how her Grandmother in her un-airconditioned church in Florida would have to take off her fancy church hat during church service so that she would not sweat and stain it. Faith saw this same problem space with her Grandmothers at her Great Lakes City Baptist Church. For Faith, her Grandmothers' church hats were a vital symbol of her generational and community history. Faith

[1] I use the term youth and students (as learners) interchangeably.

believed that her FANcy hat would mean that her Grandmothers could keep on their elaborately adorned hats as a symbol of their cultural-historical embodiment of resilience and uplift. For her family, she wanted to make sure that medical conditions did not lead to heat stroke or other physical ailments, particularly in the head/face/neck area. For her friends in track, her hat could be used to limit exposure of cancer-causing sunlight rays. These were all critically intersecting and important areas of concern for her. Hence, the FANcy hat was created by purposefully hybridizing Faith's home and community knowledge(s)[2] and practice(s)[3] , STEM knowledge(s) and practice(s), and criteria and constraints of engineering design process in ways that first and foremost considered the aesthetic/functionality needs of her community (Nazar, Calabrese Barton, & Rollins, 2017).

Now, an 11th grade student in Great Lakes City, Michigan, Faith constantly looks back at her work done at her local Community Center. She has described these accumulated experiences as "important to think about what I can do in the future" (Chapter 3, Interview 2). During her time in the green energy club, Faith stated that the engineering design work she completed helped to "take care of her community" (Chapter 3, Interview 1) in ways that traditional school curriculum and teachers did not support her in doing.

Furthermore, Faith shared with those teachers that she was *doing science and engineering in meaningful ways*, but her teachers never built on these experiences—either to support her learning or to help her share her valuable knowledge(s) with her classmates. To this day, Faith continues to discuss how her schooling experiences focus on standardized testing, memorization of

[2] I include (s) at the end of knowledge in this dissertation to emphasize that there is no one type of knowledge, but multiple knowledges and ways of knowing and being that are important and should be leveraged in K-12 science learning

[3] I include (s) at the end of practice in this dissertation to emphasize that there is no one type of practice because they are dynamic and remnant of an individual's collective historical, cultural, linguistic and social positioning.

science facts and discourse and limited engagement in critical thinking/hands-on ways. She has discussed fears that her schooling will not support her in developing knowledge(s) necessary to become an engineer. She feels it has become her responsibility to acquire the knowledge(s) necessary to be competitive enough to gain admission to Midwestern Research University (MRU) upon her graduation from high school in Spring 2019. Upon analyzing these experiences, Faith has agreed that youth like her should not have to find ways to educate themselves in ways that are meaningful to them, but that teachers and schools should learn to view youth as community experts in their classrooms and build on these and their interests in their science learning. This is why she told her story. My goal is to center stories such as Faith's that detail her meaningful science learning, as learning tools for teachers and preservice teachers (henceforth referred to as PSTs). I want youth to be recognized as experts in their own science and engineering learning.

Faith's story and her experiences as a science learner is one that is too often heard, of youth, particularly those from minoritized[4] communities, who enter science, technology, engineering and mathematics (henceforth STEM) with their own unique cultural repertoires of practice (Gutiérrez & Rogoff, 2003). Yet many of these youth' cultural knowledge(s) and experiences are not recognized—by teachers and important brokers in their educational success—as legitimate resources for learning and engaging in/with STEM. Long term studies of underrepresented groups in science and engineering discuss that identity development is crucial to how and why individuals ultimately pursue STEM trajectories (Johnson et al., 2011). If science

[4] The term minoritized, vs. minority, indicates that an individual's minoritized status is a function of how that individual is positioned within a hegemonic society, rather than an inherent descriptor or trait (Gillborn, 2005). The term 'minority' is recognized in critical scholarship as a deficit term and an inaccurate reflection of demographics in many communities in the U.S. where individuals of color represent the majority of the population. I use minoritized and People of Color interchangeably throughout this dissertation depending on how I view positioning or description/trait in relation to the systematic done onto these communities and how it fits within the argument I am making.

education wants youth to achieve in science—but most importantly pursue STEM career trajectories and have confidence to critically engage STEM as they need and wish to in their lives—the field must make sure that their science experiences are not only connected to their lives and educational pursuits, but also that science learning is connected to their futures and the social relationships they value (Basu & Calabrese Barton, 2007).

This in turn also speaks to the science activities that teachers, in school spaces, should design to make STEM meaningful to youth. Teachers through recognizing youths' cultural knowledge(s), practice(s), and experiences can help youth enact their views and purposes of science in their learning (Basu & Calabrese Barton, 2007). According to Faith, her experiences in school and her account of teachers failing to recognize her out-of-school experiences has created deep divides between who she is as a learner and who she wants to be as an engineer.

Although Faith feels she created a space to have these concerns legitimized through participation in the after-school club, her primary concern was how her teachers would support/legitimize who she was and the community knowledge(s)/practice(s) important for her school science learning. For Faith, these connections are important, as they are milestones to be and achieve in STEM (Basu & Calabrese Barton, 2007). However, given her interest in becoming an engineer and the limited K-12 support she has received in her schooling experiences, Faith needs to find out-of-school experiences that will legitimize these interests. For example, in her goal of becoming a psychoengineer, she wants to use engineering as a treatment for people suffering from mental health. Through her own research, she has found ways to merge these interests in educative ways.

Science educators and teacher educators do not do enough to center the ways culturally diverse youth come into their science learning. Practices are needed that will support an inclusive cultural, linguistic and economically diverse youth in science education. Hence the focus of this dissertation on how counternarratives about science and engineering from youth like Faith can become critical junctures in connecting teacher education with youth knowledge(s) and practice(s).

As with Faith, I co-created multimodal cases with two other youth who participated in the after school green energy club. In these cases, the youth discussed how participating in the club created experiences to merge science learning with their community knowledge(s) and practice(s). Most importantly, they used these cases as a way to challenge the narratives told about them in their science/engineering learning by challenging ways adults/teachers/PSTs could learn about them through a lens of power and privilege. Most importantly, they discussed important stages in their design process and how they hybridized their community knowledge(s)/school knowledge(s)/family practice(s) in ways that were meaningful and transformative for their own learning.

Making the Connection: Learning from Youth Lives in Teacher Education

Challenges to youth science interest, motivation and engagement are most critical in the transition between elementary to middle school (Tan, Calabrese Barton, Kang, & O'Neill, 2013; Vedder-Weiss & Fortus, 2011). These challenges include connections between factors, such as science engagement, interest, and goal orientations, school contexts and culture, classroom pedagogy, peer influences and home environments in their learning (Carlone, Scott, & Lowder, 2014). Important to these aforementioned connections is also the role teachers play in recognizing how their teaching sustains cultural experiences in student learning (Birmingham, 2013; Paris & Alim, 2017).

In this dissertation, I argue that, PSTs' learning to teach needs to include ways that sustain/value/legitimize/leverage youths' cultural knowledge(s) and practice(s) in STEM *education. By being educated to support these knowledge(s) and practice(s) in their teacher learning, PSTs can create opportunities to merge youths' lived experiences in way that support them in authoring new social futures towards a meaningful STEM education. Faith's vignette illuminates these important connections.*

Faith's vignette is a reminder of how school science is too often focused on acquisition and transmission of knowledge and general processes of scientific practice (Lemke, 1992; Newton, Driver, & Osborne, 1999; Rudolph, 2002). Lee and Roth (2003) argue "current practices of science education focus on youth' conformity to authoritative knowledge and scientific discourse that are relevant to research scientists" (p. 404). This lack of connection to the world in which individuals live and interact isolates scientific knowledge/practice from individuals lived experiences and those of their community life (Gruenwald & Smith, 2008; Nazar, Calabrese Barton, Morris, & Tan, accepted). Not only that, but for youth from minoritized communities, this focus on authoritative knowledge(s) further exacerbates the social/historical/political gaps and debts already existent and detrimental to their education (Ladson-Billings, 2006) and science education in particular.

With renewed focus on science education reform (e.g., the Next Generation Science Standards, (NGSS) it is important that science content knowledge(s) and practice(s) are built coherently across K-12 (NGSS Lead States, 2013) with science education focusing on deeper understanding and application of content in ways that support integrated science learning experiences, emphasizing engineering design and technology applications in the real world (NGSS Lead States, 2013). This type of learning cannot be divorced from youth' home and community practice(s). Important here is how building from youth's cultural repertoires of practice (Gutiérrez & Rogoff, 2003) expansive learning opportunities can be created by purposefully merging disciplinary (vertical dimensions) and space/time (horizontal dimensions) (Engeström & Sannino, 2010) between youths' lived experiences and their science learning.

It is my belief that teachers should be supported and educated in opportunities to fully engage with these practice(s) in assets-based ways by recognizing that youth like Faith and the home/community experiences and practice(s) that are important to them. But also, that these meaningful experiences and practice(s) also become educational opportunities for teachers as they are supported in developing pedagogical commitments and beliefs towards teaching in equity-oriented ways. By doing so, these teachers can generatively (re)shape their practice(s) towards ways that meaningfully support youth from minoritized/socially diverse backgrounds in culturally sustaining and pluralistic ways (Paris & Alim, 2017).

Hence, teachers are—and will always be—an essential part of supporting student identity and agentic development in science for all youth (Calabrese Barton & Tan, 2010; Carlone et al., 2014). Yet, there are limited studies that show the impact that learning from youth's out-of-schools science experiences have on in-service/PSTs. One study focuses on "equitably-consequential" science education that is rooted in the local histories of youth, supports rigorous engagement with and connections among science and broader social issues as well as shifting power dynamics to youth and supporting critical science agency in their K-12 education in equity-oriented ways (Birmingham, 2013; Birmingham, Calabrese Barton, McDaniel, Jones, Turner & Rogers, 2017). Other studies have also discussed the importance of how teachers make sense of youths out-of-school science experiences (Birmingham, 2013). However, there is a large gap in understanding how youth STEM knowledge(s) and practice(s) can inform preservice teacher education.

Historically, preservice science teacher education experiences have focused primarily on the changing ways science is taught in schools—mostly through how science content is presented in standards, engaged through inquiry-oriented practice(s), and ultimately these are assessed to reflect student learning (Windschitl, 2003). For others, the focus is on develop a set of teaching practice(s) that are ambitious through deeply-engaging and rigorous application content and practice(s) (Jackson & Cobb, 2010). In other cases, the focus is on developing a scientifically literate workforce able to compete technologically and globally in our 21st century economy (NGSS Lead States, 2013). However, there needs to be better understanding of how PSTs are supported to reflect and enact practice(s) as they move through their teacher education programs (Feiman-Nemser, 2003).

In addition, conversations in science teacher education are needed to understand its role in renewed STEM policies to be enacted, such as the Next Generation Science Standards (NGSS Lead States, 2013). It is necessary to unpack how equity-oriented frames of mind for future teachers are supported generatively through their preservice programs. Particularly, in how beliefs, practice(s), youth and community practice(s) become important and consequential in their youth' science learning over their careers. The need to focus on the changing views of policy to practice(s) in science education given recent calls in standards provide a unique problem space to support PSTs to develop an equitable science education for youth in the future classrooms they will teach.

Hence, researchers and teacher educators must recognize that there is a need to focus efforts to support youth-centered, equity-oriented science teaching--especially in developing these practice(s) early on in preservice teacher education. Focusing this work in preservice teacher education can open up expansive learning opportunities to support rigorous engagement of science rooted in local histories of youth. Youth-centered, equity-oriented science teaching also asks us to engage in practice(s) that are concerned with shifting expertise towards youth, especially as owners of their own histories and experiences in ways that uphold their experiential realities and those of their communities. This type of teaching/learning also asks us to challenge essentialist notions regarding histories and experiential realities (Solórzano & Yosso, 2002) of youth and their communities in our science teaching. At the same time, this work focuses on how to recognize the education debt that is owed to minoritized youth and how educational outcomes are inherently tied to ways youth are minoritized, historicized, politicized, racialized in society and in in their schooling (Ladson-Billings, 2006). Lastly, important to this conversation is how/in what ways PSTs are educated and supported to develop these rigorous, equitably consequential practice(s) (Birmingham et al., 2017) in their teaching.

Thinking about how to critically engage PSTs in developing these youth-centered practice(s), in this study I focused my co-development of a methods course on learning from/with stories of youth, such as using multimodal artifacts produced by Faith and other youth who participated in the green energy club.

The role of multimodal artifacts such as videos to support teacher education has been an important area of study for many years (Sherin & van Es, 2005). Studies that use multimodal artifacts of classroom interactions in preservice teacher classrooms are not new. Abell, Bryan, and Anderson (1998) investigated preservice elementary teachers' theories about science teaching and learning through their reflections on integrated media case-based instruction of a seeds and eggs lesson. The authors found that the videodisc cases provided a virtual world for PSTs to make sense of their own preconceptions of theories of science teaching, and subsequently how the teachers in the video responded to youth based on the interrogation of these same questions.

Other studies have discussed the potential of using multimodal artifacts to guide PSTs in activating, acquiring, and applying knowledge(s) in meaningful ways (Abell & Cennamo, 2003;

Brophy, 2013) by bridging gaps between theory and practice(s) and supporting these teachers in in applying what they have learned at the university in actual classroom lessons (Bloomberg, Renkl, Sherin, Borko, & Seidel, 2013). Essentially the use of multimodal artifacts offers PSTs a “window” into teaching, “without the pressure of interacting” in a classroom situation (Sherin & Han, 2004).

Although this study is not limited only to how PSTs learned to teach taking up multimodal artifacts, I do believe it is one way to support PSTs in seeing parallels between youth’s views of science learning and knowledge(s) and practice(s) in science. This dissertation focuses on PSTs uptake of youth knowledge(s) and practice(s) in STEM, but how this uptake provides meaningful opportunities to merge knowledge(s) and practice(s) with lived experiences in ways that support youth in authoring new social futures. Not only by thinking about who one is (identity) and who one wants to be (agency) but also what one wants to do and for whom—especially learning to support this work in meaningful ways.

I believe that this new approach can provide a new “window” into PSTs developing equitable practice(s) in STEM teaching and learning. Primarily by focusing on how youth knowledge(s) and practice(s) can drive the learning to teach of science in an elementary methods course.

Articulation of the Problem and Research

Inequities in educational attainment and participation in science persist for youth from minoritized backgrounds in the United States (National Center for Education Statistics, 2011). Despite decades of science reform efforts, severe gaps in achievement and interest remain, predominantly for Black, Latino and youth from low income communities (National Science Foundation [NSF], 2014). These gaps have created lasting effects such as limited opportunity and access to high quality academic preparation in science (e.g. critical literacy and future sensemaking of personal, community, and global issues) as well as pursuit of high demanding, science-related career choices. More importantly these gaps add to the accumulated socio-political, economic and historical education policies that have aimed to disenfranchise Youth of Color in ways that limit their contribution and success in education and society (Ladson-Billings, 2006).

In his landmark piece, *Science Education as a Civil Right: Urban Schools and Opportunity-to Learn Considerations*, Tate (2001) describes that urban science education is a civil rights issue. To effectively address it as such, arguments must be shifted from civil rights as shared physical space and equity in resources in urban schools that serve a high number of minoritized low income youth to demands for high quality-academic preparation that includes the opportunity to learn science—such as supporting the development of highly qualified teachers. Teacher quality has been traditionally associated with strong subject-matter knowledge, pedagogical knowledge, and years of experience, behaviors and practices that leads to success (Darling Hammond, 1999). Furthermore, focusing on how these qualities have been known to influence student success, and opportunities to learn science (Tate, 2001). However, this conversation of supporting highly qualified teachers should be further shifted towards supporting their development in practice(s) that focuses on leveraging cultural strengths and repertoires of practice (Gutiérrez & Rogoff, 2003) of youths' science learning.

To lessen the gaps of accumulated debts done by socio political, economic and historical education policies (Ladson-Billings, 2006), especially in STEM that have disenfranchised so many, then developing these equity-centered practice(s) should be a goal during preservice teacher education programs.

In developing these practice(s), teachers have been supported to engage in such inquiry into practice by analyzing student-generated artifacts and seeking relationships between learning and instructional moves made in the classroom (Curry, 2008; Little, 2007). In addition, teachers also use classroom discourse and teaching tools to enhance science talk and engagement in scientific practice(s) (Windschitl, Thompson, & Braaten, 2011). However, there is a large gap in the teacher learning and teacher education literature that aims to understand how teachers can be supported to develop teaching practice(s) to better support youth from minoritized backgrounds in equity-oriented ways. Learning from youth calls attention to how learning and engagement in science are rooted in histories and geographies of young people who discuss rigorous engagement with and connections among science, community and broader social issues in pursuit of transformative outcomes and shift power dynamics in their community (Birmingham et al., 2017).

In summary, the problem spaces that this work addresses are around how/in what ways PSTs can be supported to develop youth-centered, equity-oriented science teaching practice(s) during their teacher education programs—from youth counternarratives of their engagement with meaningful science & engineering learning—so that these future teachers recognize the potential of their work to support minoritized youth in obtaining an equitable science education. Furthermore, this recognition and potential for social change by teachers can provide youth access, positioning and recognition in STEM but also provide perspectives and tools on what counts as learning for youth. The goal is that PSTs incorporate these assets-based approaches in their teaching. This work may lead to a socially just science education with providing PSTs with the tools to position themselves and recognize the power they have to eradicate the social, political, historical, cultural disenfranchisement of youth and their communities in (science) education.

Positionality in this Work

This is my positionality statement regarding the personal, social and cultural development of my education which is intertwined in this dissertation. This cumulative work is a compilation of over fifteen years of my own educational experiences—as a K-12 student, university student and researcher. However, methodologically, this work has been developed in five years of close longitudinal and participatory work with youth in communities and with PSTs which the methods sections of each of the papers will describe in further detail.

Onto-epistemologically, this dissertation is also a result of my own sensemaking regarding the culturally and linguistically diversity in my own science education. I, for too long, have suppressed much of the cultures that the define me, especially in academic spaces. Because I believe cultures/ways of knowing and being/everyday experiences at home, with family and friends, and even our languages and sensemaking of experiences are crucial to how youth feel welcomed, identify, are recognized, succeed and become in science, this dissertation is an attempt to bring these ways of knowing to light in how other PSTs learn to engage with them.

My name is Christina Restrepo Nazar and I proudly use both my given name and my mother's maiden name. I was born in Teaneck, New Jersey, but grew up on 80 Passaic Ave. in Passaic, New Jersey. I am an only child born to Colombian immigrants. My mother— born to a Colombian woman and Palestinian man —is a retired janitor. Most recently, she worked as a janitor at the University of Central Florida (my alma mater). My father as a young man, worked as a coffee farmer in rural Colombia. He immigrated to the United States and worked in a factory until he suffered injuries from a car accident. The accident left him permanently disabled.

Although my parents separated when I was a child, and the relationship I had with my father was severely strained, I was lucky to have the love and care of my entire maternal family.

My aunt, Sofia (now 84) helped raise me as my mother had to work two jobs to support our household. My uncles, who now live in Puerto Rico, served as my “fathers” and raised me as their daughter due to my father’s absence most of my life. My family never missed a school event, or an important milestone in my academic career and I owe them the foundations of my entire success as they taught me to achieve the most I could no matter the circumstances. In addition to these experiences, for my family, it was extremely important that I grow up taking up on my heritage. They never allowed me to speak English at home, and they resisted me taking up on what I would now call “white mainstream culture.”

One of the greatest lessons I will remember from my family is that our cultures, languages, and what we have experienced are things that no one can take away from us. To them, they believed that we have a choice to bring out who we are, which was their experience in Colombia. However, upon continuing my studies and being a part of the greater academic culture, I find that in America this is not the case. We are constantly judged, positioned, recognized by exactly who we are, the language we speak, the color of our skin and ultimately how we present ourselves to others which I would combinedly call: our practice(s). The practice(s) that made me a successful member of my family and close social circles were actually working against me in the greater academic and “white mainstream culture” circles I had moved into as I entered my postsecondary education.

However, as I moved through these five years in my doctoral career, I now came to understand why they said this to me. They, too, endured the difficulties of assimilation for various generations. My grandfather, Hasan Mustafa Abed Rabbo (who took the name Jose

Miguel Nazar upon his arrival to Colombia) left his native Beit Safafa, Palestine (now Israel) to avoid being recruited in the Turkish Army (then the Ottoman Empire) at the eve of World War I. He essentially left behind his culture, family and his life—one he never returned to. By his family, I mean his wife, Fatima and young son, my uncle Mustafa. He never spoke of his family in Palestine, however he communicated with them through letters and sent pictures of my uncles as they were growing up in Colombia. I believe he did not talk about them not because he wanted to forget about them, but because he was in the crossroads of cultures and history took its turn. Colombian churches would not register my aunts and uncles with Arabic names which he tried to do many times, eleven times to be exact (each time an uncle/aunt of mine was born). It became evident that in that small village, Andes, Antioquia, it was frowned upon to be Middle Eastern and take up on their customs--especially the Arabic language and the Islam religion. My Grandmother, Mercedes Bernarda took a great risk in marrying my grandfather, but instead of him fighting to have these cultural and linguistic repertoires to be recognized, he lost them as he raised his children. Ultimately, his Middle Eastern culture was silenced and then so were my family.

As my family notes, the Palestinian Diaspora in Colombia had a very tight knit community, but many of those men and women that immigrated decided that the best course of action was to assimilate their children into the new culture, which became the case for my family. Now, as technology and globalization became increasingly part of our lives, the diaspora is struggling to find their roots--one that I and many other descendants who are trying to find our families and retell our stories together.

As my Colombian aunts and uncles grew up and began setting their eyes on new opportunities, it became evident they needed to seek economic, social and political changes. My grandfather no longer had his businesses, and my family was struggling financially. Just as my grandfather did decades before and after his death, my aunts and uncles too decided to leave it all behind and come to the United States. However, here too was another dilemma. They grew up not knowing or learning about their Arab culture, and here they began to see the assimilationist practice(s) that forced them to leave their Colombian roots too.

When I came along in the 90's I saw that Colombian immigrants, especially friends of my aunts and uncles in New Jersey, held reunions and societies (called cofradias) mainly based at churches to maintain their cultural traditions. At times it felt like we were hiding. Others talked about sending their children back home so that they would not "lose their Spanish." Such was the decision my mother made so that I traveled to Colombia every summer. My parents immediately gave me Colombian citizenship to avoid paying penalties for my stay as an American Citizen in the country. Throughout the 17 years for my U.S. summer vacations from school, I traveled to Colombia and stayed with my aunt Sonia who taught me to read, write and speak Spanish fluently. She was also the closest daughter to my Palestinian grandfather, and taught me to love, appreciate and understand his culture through the limited stories my grandfather told her. I am lucky, as I am the only grandchild to know and own all of my grandfather's cultural artifacts. Because of these intersecting identities, I consider myself a milieu of my three home cultures: Colombian, Palestinian and American.

Although I identify as a Latina in my current academic spaces, as it is difficult to say and further explain that I am Arab Colombian American, or to go into further explanation about the experiences that made me who I am especially because that is what I look like and that is how I am perceived by others. In Colombia I do not look Colombian, here I don't look Latina enough, and in my communication with my cousins in the Middle East, I don't know the language or the culture and religion--then who am I?

The point of this narrative is to explain that these experiences taught me to be sensitive and appreciate diverse cultures and perspectives, but to also see that when one's cultures and perspectives are not a part of one's learning or even suppressed—they can seriously inhibit our own belief in ourselves to be successful. I had the privilege of having two amazing teachers, Ms. Denise Brown-Ramsey and Mr. Paul Schmidt (he was also my biology teacher and got me excited about science) who cared deeply about my education--even caring about who I was, who my family was and how that all was important to me. But I also had teachers that would marginalize me and penalize me for speaking another language, or for challenging "what the book said." Such was the case in fourth grade where I was constantly pulled out of the class and received bilingual and support services because the teacher believed I could not speak proper English and thus learn in the mainstream classroom. This experience was detrimental to my success, and it wasn't until eighth grade with Ms. Brown-Ramsey that I was supported to learn in ways that were the best for me.

This positioning narrative aims to explain my personal connection to this work. Particularly how different teachers' perceptions of who youth are and what they bring to their learning can shift and change the responses of how one as a student sees oneself in one's learning and potential to be successful. These perceptions may be a result of cultural, linguistic, and racial differences, and these can have dire educational consequences on youth. We need to challenge our discourse when we mean youth can't, or don't know, but rather shift it to what teachers can do to learn and better understand youth who hold diverse cultural and linguistic repertoires and support them in ways that are true to who they are. These are discourses that need to drive our ways of viewing education, and science education specifically because of its long epistemological, methodological and ontological history of exclusion and gatekeeping.

Growing up with these experiences are what drives my ontological being as I work through my methodological and epistemological perspectives. “Research-wise,” I try to provide as much long-term understanding of the youth and adults I work with because I feel it takes a village to understand the perspectives, cultures, knowledge(s) and practice(s) of individuals and it becomes much more complex as those individuals interact with their communities to show you those practice(s). This is why I strive for long-term engagement and long-term impact in my teaching and research.

As researchers, teachers, and policy makers who will develop education policy in the future, we cannot treat these issues of educational inequities and youth-centered work/experiences/knowledge(s)/practice(s) as separate entities. They are interrelated and dependent on each other and a long part of what will become or life’s educational histories. Hence, research on youth knowledge(s) and practice(s) can and is connected to how PSTs learn to become classroom teachers because ultimately how they teach has great and unsurmountable impacts on the youth who learn from them.

I want science teachers who are learning to teach to start where the youth are by hearing their stories and learning to shape their teaching based on how they make sense on what best exists to support them—I believe this dissertation can help support this line of inquiry.

Purpose, Research Questions and Dissertation Structure

The purpose of this dissertation is to understand how/in what ways a science methods course that focuses on youth knowledge(s) and practice(s) helps support PSTs in imagining and enacting practice(s) in classrooms in youth-centered, equity-oriented ways. Foregrounding the voices and experiences of youth who worked in an after school green energy club at the Community Center of Great Lakes City from Fall 2013-May 2015 and PSTs who participated in a science methods course Fall 2017 (Midwestern Research University) and field teaching experience in Spring 2018 (Great Lakes City, Liberty Spanish Immersion School). I look at how *counternarratives of the culture of power in science* can help to better design methods courses that attend to these aspects of youth knowledge(s) and practice(s) in preservice science teacher education. I report on three separate, but interrelated qualitative studies connected through the lens of social practice theory (Holland & Lave, 2009).

The research questions under investigation are:

1. What *counternarratives of the culture of power in science* and meaningful science learning experiences do the youth describe in their co-authored multimodal artifacts of science and engineering learning?
2. What pedagogical imaginaries do PSTs hold of youth knowledge(s) and practice(s) in their learning to teach of science? How do these pedagogical imaginaries inform their initial views of youth-centered, equity-oriented science teaching practice(s)?
3. In what ways do preservice elementary science teachers enact *youth-centered, equity-oriented (YCEO) science teaching practice(s)* in an engineering unit focused on sustainable communities? How are these youth-centered, equity-oriented teaching enactments shaped by local contentious practice(s) ?

The structure of the dissertation involves using three interrelated studies to address the three research questions.

The first study and RQ #1 explores how youth from an after school green energy program developed online multimodal cases of meaningful science learning that focus on counternarratives of the culture of power in science based on engineering designs they created for sustainable communities-- including the process they undertook to make them. These designs included a duct-tape thermometer tie, anti-bully cell phone application, and a solar-panel fan-hat. In their cases, AD, Faith, and Christopher included videos, audio recordings, pictures, and text in the multimodal artifacts produced and described important counternarratives that challenged schooling experiences in ways that they were raced, classed, and gendered but also how the expansive learning outcomes challenged the normative culture of who/how/when/and where science and engineering can be done. This research has important implications for challenging the culture of power in science education, especially in how youth position themselves so that in-school and out-of-school experiences are legitimized and taken up by important others. This legitimization affects the ways youth feel recognized and positioned and ultimately supported to take action in what/whose knowledge(s) counts in science and engineering. The findings of this paper will be discussed in chapter three.

The second study and findings from RQ #2 focuses on how seventeen elementary PSTs, during their science methods course at Midwestern Research University (Fall 2017), developed pedagogical imaginaries during a science methods course focused on teaching science to diverse learners. Using imaginaries as practice, this paper aims to understand how their learning to teach experiences--both in the methods course and in the field--contributed to supporting imaginaries in youth-centered, equity-oriented ways. Specifically, how the combination of class assignments, discussions, and youth-authored multimodal materials supported the development of equity-oriented, youth-centered pedagogical imaginaries in planning and designing for their class field teaching experiences. As a field, science education is pressed to develop a successful repertoire of teaching practice(s) that support youth in engaging in/with science content and standards in culturally-responsive ways. The findings of this paper will be discussed in chapter four.

In the third study, using enactments as practice, I follow three youth from the Fall 2017 science methods course in their student field teaching experience over the course of six weeks where they worked as student teacher/researchers on an engineering for sustainable communities' unit at Liberty Spanish Immersion School. To answer RQ #3, I discuss how PSTs worked to enact youth-centered, equity-oriented (YCEO's) teaching practice(s) and how these experiences shifted over time as they made sense of their own history-in-person and the institutionalized struggles evident in the local contentious practice(s) of their classrooms—and how these ultimately shaped the uptake of youth' home/family/community science and engineering practice(s) in teaching science. In addition, implications for field teaching towards enacting practice(s) can be shaped by school culture, expectations of teacher mentors, and sensemaking of curriculum materials to support student learning. The findings of this paper will be described in chapter five.

Chapter six in the implications section, I briefly discuss connections between the three papers in three major findings that that can support a future line of inquiry in equity-oriented science teacher education.

It is my belief that science education must shift preservice teacher education from providing "windows" of opportunities into teaching to a new sociopolitical shift in building awareness and value youth knowledge(s) and practice(s) as important resources for learning. Also, important is how making sense of these dynamics can result in expansive learning (Engeström & Sannino, 2010) for PSTs as they too make better sense of their teacher knowledge(s) across spaces and over time. This sensemaking can allow them to question their own privileged positions and implicate themselves in the classrooms they will teach. By learning to take up student counternarratives, the unbalanced power dynamics between youth and teachers can be disturbed and give way to recognizing how race, class, gender, and other hegemonic structures have contributed to historical gaps in STEM learning.

Significance

Returning to Tate's (2001) argument of science education as a civil right, even though standards focus on supporting all youth in an equitable science education, the field cannot further ignore that minoritized youth have been historically disenfranchised from a socially just science education, where understanding of youth knowledge(s) and practice(s) are understudied and underused in preservice science education courses. Teacher education has focused primarily on individual interactions with limits to how it can be used to push back against systems of oppression. My goal is to disrupt knowledge(s) hierarchies as to whose knowledge(s) matters in the learning to teach.

Furthermore, I want these developing science teachers and their practice(s) to be in dialogue with how they view their field placements in transformative ways. Sociopolitical shifts, which focus on unpacking these power dynamics, interrogating whose knowledge(s) counts, for whom and why it matters, are needed in preservice science teacher education.

CHAPTER TWO:
LITERATURE REVIEW

Teacher education refers to a series of educational experiences that prepare those entering the teaching profession for successful teaching careers while also providing continuing education for those already teaching (Hallinan & Khmelkov, 2001). Trends in increasing school diversity has prompted many teacher education programs to focus on preparing teachers to best meet the needs of youth who are ethnically, racially, and linguistically diverse (Villegas & Lucas, 2002). Responses of teacher education programs to increasing culturally diverse teacher education have included adding courses in multicultural education, bilingual education and/or urban education. However, in designing these courses, an important problem space developed regarding the ways these courses interact with and in supporting disciplinary content, practice(s)--which they seldom do (Villegas & Lucas, 2002) --and better understanding how content knowledge(s) for teaching is culturally specific (Cole & Espinoza, 2008).

In science education, educating teachers that are prepared not only in content-area knowledge(s), but also in developing practice(s) that meets the needs of minoritized youth has been a topic of great debate (Anderson & Mitchener, 1994; Bryan & Atwater, 2002; Windschitl & Calabrese Barton, 2016; Windschitl, Thompson, Braaten, & Stroupe, 2012). In the introduction to his paper, Morales-Doyle (2018, p. 1016) reminds us of Tate's (2001) invitation to the science education community "to engage in social justice issues to treat the opportunity to learn science as a civil rights construct" (p. 1016). Teachers now more than ever are faced with "an unprecedented level of standardization and accountability" (Morales-Doyle, 2018, p. 1016) which further exacerbates inequities across race, class and gender lines--all which have limited foci through research & practice in these in science education (Maulucci, 2012; Morales-Doyle, 2018).

However, returning to the larger goal of teacher education programs, in preservice science teacher education, there is limited research on what is consequential (Birmingham, 2013) for science teachers to know to be best prepared to meet the needs of culturally diverse and minoritized youth (Mensah, 2009, 2011; Tolbert, 2015, 2016). However, there is an increasing focus on standards and accountability (Morales-Doyle, 2018) coupled with the rarity in novice science teachers understanding of what youth know or the cultural repertoires of the youth before they enter their classrooms (Bryan & Atwater, 2002) and what practice(s) best support them. This all provides an important problem space to investigate.

In this literature review, I first begin by discussing the culture of science and science teaching. I then focus on science education reform efforts and the culture of science through one lens of teaching science for scientific literacy. Thirdly, I discuss teaching practice(s) with an eye towards a new way of supporting PSTs of developing youth-centered, equity-oriented practice(s). Lastly, I discuss how the literature conceptualizes science classroom instruction, and how a new view of youth-centered, equity-oriented practice(s) can help to shift PSTs views of science teaching towards one that is equitably consequential in their practice.

Culture of Science and Science Teaching

Bryan and Atwater (2002) discuss "that in order to prepare science teachers for teaching in classrooms whose student's cultures are different from the teacher, it is not enough to understand how [and in what ways] youth learn" (p. 825). This understanding needs to go far beyond awareness, recognition and respect for different values and ways of knowing and being (Gay, 2002). It must also include how teachers make sense of the ways inequities and oppression play out in classrooms where structures such as white supremacy, neoliberalism and heteropatriarchy are inherently part of science teaching (Morales-Doyle, 2018). Moreover, it is critical to recognize ways these aforementioned structures play out in the classroom culture and then how these lead to creating a culture towards socially justice-centered approaches to teaching science (Morales-Doyle, 2018).

In anthropology, culture is understood as “a symbolic realm which arises within the frame of social structures” (Preston, 1997, p. 38) and is “a way of life of a group of people, the sphere of complex practical activity, or praxis” (p. 39). Important also is how unspoken, unconscious, implicit knowledge(s) shape these processes and representations, and ultimately how these become important for the creation of knowledge(s) and belief systems. Bryan and Atwater (2002) discuss that teacher beliefs and cultural modes are an important part of science teacher education. In addition, teachers’ understanding of their own views of science teaching and the ways they themselves view youth culturally within this frame can shift, limit or challenge the ways teachers support youth to engage in their science learning. Unpacking these beliefs within the culture of science has important consequences for how prospective educators make sense of multicultural issues. Particularly in how teachers are educated to meet the needs of diverse learners, especially in critically consequential ways (Birmingham et al., 2017).

In science as a discipline, significant emphasis is placed on the ways observing, thinking, experimenting and validating conclusions have become a part of how people explore the world (American Association for the Advancement of Science [AAAS], 1993, p. 3). Within these knowledge(s) and belief systems, scientists have socially negotiated aspects of knowledge(s) and language that represent science--creating a culture [of power] in science (Bryan & Atwater, 2002; Calabrese Barton & Yang, 2000). This culture of science is what has primarily driven our science education reform efforts in classrooms across the country.

In the K–12 context, "science" is generally taken to mean the traditional natural sciences: physics, chemistry, biology, and (more recently) earth, space, and environmental sciences...In the standards, "engineering" is also used in a very broad way as the engagement of the systematic practice of design in order to achieve solutions to human problems. According to *The Framework for K-12 Science Education: Practices, Crosscutting Concepts and Core Ideas (*henceforth referred to as *The Framework)* "science, engineering, and technology permeate nearly every facet of modern life, and they also hold the key to meeting many of humanity's most pressing current and future challenges (National Research Council [NRC], 2012, p. 1). The goal for K-12 science education is to ensure that all youth, by the end of 12th grade, have appreciation for science, possess sufficient knowledge(s) of science and engineering to engage in public discussion, and are careful consumers of scientific and technological information for their everyday lives, in addition to being able to learn science outside of school and have the skills to enter science related careers (NRC, 2012). Science educators proposed a framework that includes three major dimensions including: scientific and engineering practices, crosscutting concepts that unify science and engineering across fields and disciplinary core ideas (NRC, 2012, p. 2). Findings from *The Framework* articulated a vision for science teaching and learning which helped create the *Next Generation Science Standards* (henceforth referred to as NGSS). The NGSS helped to align the curriculum, instruction and assessment visions of *The Framework* so that it would be implemented in professional development and preservice teacher education programs (NGSS Lead States, 2013).

However, developing views of the culture of science in relation to youth enacting views and purposes of science through *The Framework* /NGSS is under-studied in preservice science teacher education. Although this dissertation is not about how PSTs develop activities or classroom sequences using youth knowledge(s) and practice(s) through *The Framework/*NGSS, it is important to note that there are limited studies that discuss developing a youth-centered, equity-oriented view in goals for science teaching alongside *The Framework*/NGSS in PSTs science education.

In one study, Bergman and Morphew (2015) use the NGSS and partnerships with faculty in the natural sciences as a way to drive planning of science activities that the PSTs will use in their lesson planning. The authors discussed how elementary majors have reported, previous to their involvement in the course, feeling that their methods courses have traditionally been one-sided, intimidating, impersonal with substandard instruction where PSTs "receive poor examples of how to teach science to children and consume superfluous content that is inappropriate for their needs" (p. 74). After the course, findings indicated that there was an increase in the self-efficacy in being prepared to teach science and in using the NGSS. In this case—using NGSS and content knowledge(s) to develop a methods course--allowed for PSTs to learn science content specific to the learning goals they are to teach. Important here is how methods courses could be shaped in support of connecting PSTs with the goals of science knowledge(s) & practice(s). This study shows two important learning points: the first is that PSTs have pre-conceived notions related to their views of science teaching that may be upheld by ways their science methods courses support them as teacher learners. These views of methods courses being one-sided, intimidating, and impersonal can have great effects on the type of teachers they will become. The second learning point is related to how methods courses have taken recent strides to incorporate PSTs learning to teach using *The Framework*/NGSS as a way to plan for content, knowledge(s) and practice(s) instruction in science. This study is important, however, there are still limited views on how to understand ways that PSTs incorporate youth' cultural repertoires of practice (Gutiérrez & Rogoff, 2003) as part of their learning to teach. Particularly in relating to the meaningfulness of youth's science learning experiences and for planning lessons using *The Framework*/NGSS in their methods courses.

Discussions about the culture of science and science teaching related to how these play out in the planning of activities also necessitates a conversation about the goals and purposes of science learning for both why teachers need to teach science, and for youth who will learn the science in their classrooms. One such purpose is teaching youth to be scientifically literate and for what purposes. I delve into this idea in the next section of this review of the literature.

Science Literacy through a Lens of Culture: One way to Examine Science Learning for What and Whom?

In this section, I discuss scientific literacy as one way to examine what is science and for whom through a lens of culture. Learning science is connected to perspectives in how/in what ways these social/political/historicized dimensions of knowledge(s) and practice(s) can affect development in communities and literac(ies) connected to youth present and social futures' (Basu & Calabrese Barton, 2010). Hence, it is critical to examine one view of the goals for science learning especially in applications to solve community problems with the tools of science (Basu & Calabrese Barton, 2010). I take this stance and include this literature in the dissertation because of how youth in chapter three use their knowledge(s) of home/families/communities to solve problems using science and engineering. I then connect learning about youth's science engagement in/with home/family/community to PSTs by supporting teacher learning that upholds youth knowledge(s) and practice(s) in/with/through science practice(s). Understanding science literacy as an important way to view what science and for whom as goals of science learning is critically necessary.

Anderson (2007) defines scientific literacy as "the science-related knowledge(s), practice(s) and values we hope youth will acquire as they learn science" (p. 5). Hence, science educators want to produce a scientific literate populace that can use the tools of science to solve important problems presented to them for now and in the future (Anderson, Holland, & Palincsar, 1997; Lee & Roth, 2003). However, there are differing opinions and approaches on how to develop scientific literacy and for what purposes in K-12 youth. Especially when scientific literacy is discussed this in terms of culture of science and its role in science teaching, the question becomes: science for whom and for what purposes?

DeBoer (2000) discusses the goals for teaching science based on the historical meanings of scientific literacy. The author argues that the history of scientific literacy within science education in its teaching and learning was primarily a cultural force, and that science is part of our cultural heritage that should be passed down from generation to generation. Also, science provides youth with awareness of science-related career choices and successful employment where knowledge(s) of science has (had) direct implications on everyday living. In addition, understanding science allows to make greater sense of social and technological issues. Science also allows a method to view how the world works such as examining the validity of data and our conceptions of validity and bias. Yet, it is known that this focus on validity and bias in viewing science teaching and then the sociopolitical agendas that shape the cultural capital reproduced in K-12 science education, created a culture of power in science education. In addition, the lack of opportunity in science, especially those youth who do not already fit the assimilationist practice(s) of the culture of power, ended up creating a culture of power of science as well (Calabrese Barton & Yang, 2000). This understanding has critical implications supporting a more equitable and critical science teacher education--one of the goals of this dissertation.

In another perspective related to scientific literacy, Roberts (2011) splits the literature regarding the goals for scientific literacy into two separate visions – one promoting the "canon of orthodox natural science, that is, the products and processes of science itself" and one interested in "situations with a scientific component, situations that youth are likely to encounter as citizens" (p. 730). The first vision focuses on the knowledge(s) and abilities needed to be scientifically literate leaving the application largely to the individual or group (e.g. why should I not put too much sugar in my coffee?), where the second vision is focused on contextual applications of these knowledge(s) and processes (such as applying scientific knowledge(s) to solve community problems) (Feinstein, 2011). Shifts are necessary to support an application of scientific knowledge(s) to solve community problems.

Traditionally, school science has focused on providing general knowledge(s) and processes, thus relying on individuals to apply them. However, Anderson (2007) has discussed that youth in schools are not given the tools to take action on this knowledge(s) in order to make important scientific decisions. He argues: "our institutions of formal education do not help most youth to learn science with understanding" (p. 5) Without understanding, Anderson argues youth are denied access to communities, are unable to engage in meaningful work and fail to consider important perspectives when making decisions and taking actions. In addition, compounding the aforementioned idea of students not given tools to take action with the science education and the already exclusionary culture of science that has been created towards individuals, especially those whose collective cultures historically are not--and have not been-- a part of the culture of science, these have created and continue to create surmounting consequences collectively for these minoritized youth and their communities in society.

Given both the need to support youth to learn science with understanding (Anderson, 2007) and the reproduction of the culture of power in science (Calabrese Barton & Yang, 2000) which has had historical implications on youth' opportunities to achieve in science, the historical burden is being widened of why learning science is important for youth and their communities—especially minoritized youth where our educational debt to them is significant (Ladson-Billings, 2006).

Instead, I argue towards Roberts (2011) second argument that science literacy should involve considering community problems and practice(s) as a goal of science learning. This should also be a focus of preservice science teacher education.

Through this notion of Roberts (2011) in regards to considering community problems and practices, I echo Feinstein's' (2011) argument where scientific literacy should be converged with those of public engagement and connected to discourse of personal ambitions, conversing, and debating with others while also localizing cultural and community contexts to goals for science learning (Feinstein, 2011). Engagement with science in this way would invoke an emotional investment and dialog among social groups but would also allow scientific literate people to be competent outsiders and see scientific ideas as meaningful and connected to lived experiences that are socially and politically (implying analysis of power within the learning of science) connected to their lives.

Allowing this approach to be central in teacher education courses allows to further understand how youth voice—and the implication of power in their experiences—can be connected to local and important issues in communities. However, by teaching PSTs these socio-historical-political dimensions in the goals for science, spaces can be created for these narratives that counteract the culture of power that science has upheld and reproduced to be part of these contextual applications in science learning in their developing practice(s).

Calabrese Barton and Tan (2010) describe one type of science literacy that embraces "the broader notion that individuals ought to have facility with the big ideas and practice(s) of science, and privileges critical engagement with text, ideas, and the ways of knowing and being that frame the discourse of science" (p. 210). They call this, critical science literacy. Not only is this about being critical with the knowledge(s)s and discourses of science, it is also acknowledging the social networks that exist in the learning and doing of science that either legitimizes/delegitimizes the "knowledge(s), experiences, identities, and practice(s) one brings to the work." In the case of the Calabrese Barton and Tan (2010) piece, they were talking about critical engagement of science. This critical engagement can be tied to personal scientific decisions and its impact on structures of power that affect political/social/cultural decisions of society more broadly, and that collectively, individual decision making of socio-scientific issues influence these outcomes.

Take for example the emerging focus on engineering for sustainable communities. This is an approach to engineering that makes sense of the interplay between the technology of design and the needs of communities (Schneider, 2010). Not only does this approach situate engineering design within local contexts, it also espouses the importance of participatory practice(s) and humanistic action-taking towards the integration of place with the practice(s) and outcomes of engineering. Engineering for sustainable communities deals with problems and design solutions for the real world. Engineers often tackle difficult, interdisciplinary problems that are grounded in conflict, crisis and disaster. Such design problems are often tied to human rights, economics, and oppression, and they have clear technological and social dimensions. Examples range from local problems of building architecture to global concerns such as water quality and access (Schneider, 2010).

This focus to solve contextual problems in community is necessary and important, but I argue there is a severe gap in how to support these understanding and perspectives in teacher education programs, or even how to merge science teaching and learning content and practice(s) with the "understanding" that Anderson argues for and cultural repertoires youth already bring to their classrooms. In addition, how building this understanding into more community-based approaches that allows to see problems of communities, and more broadly, how those problems compare to other social/cultural/historical/political issues between other people and communities (e.g. racism, sexism, redlining, economic access). Although my dissertation is not on how PSTs view or take up science literacy and for whom, it is important to note that goals for science literacy are always at play in ways science teaching and learning functions in the classroom. The question is: who should science be for and why?

In the next section, I delve into literature regarding teacher education and teaching practice(s).

Teacher Education

Over the past two decades, preservice teacher education has seen remarkable amounts of policy directed towards improving and preparing the best, most qualified teachers to teach America's diverse student population (Darling-Hammond, 2010). Yet the "work of teaching"

(Ball & Forzani, 2009) is often contested where debates center around what teaching practice(s) contribute to a teacher's success in our nation's multicultural, multilingual, and multiethnic classrooms. For the most successful educators, their capacity to teach grows out of a professional repertoire that is "complex, relational, grounded in deep understanding of subject matter, and adaptive to learner's needs" (Windschitl et al., 2012). However, teacher education programs do not always educate teachers towards developing this trajectory in their teaching practice(s) (Windschitl et al., 2012). Most preservice teacher education programs focus on material activities, and reflections of how they themselves were as youth, or how they were supported by their teachers in their own K-12 learning (Levin, Hammer, & Coffey, 2009). Instead, PSTs should be educated in activities that are meaningful for their future youth in ways that attend their youth' learning while reflecting and developing in their practice(s) (Levin et al., 2009).

In terms of research, the literature base in teacher education is not well defined (Windschitl et al., 2012). More research on specialized programs in teacher education fare the best since there is a larger literature base from these type of programs (Boyd, Grossman, Lankford, Loeb, & Wyckoff, 2009; Darling Hammond, 2010). Also, graduates from these programs have rated their programs highly while they too have been evaluated effectively by their education program supervisors (Boyd et al., 2009; Darling Hammond, 2010) adding to the literature base. In addition, these districts also tend to recruit from this type of specialized teacher education programs for jobs (Darling-Hammond, 2010).

Darling-Hammond (2010) discusses that the successful features of these preservice teacher education programs include (1) programs that place careful attention and oversight to quality of student teaching experiences; match between context of student teaching and later teaching assignments (e.g. grade levels, subject matter and types of youth); (2) increased amounts of coursework in reading and mathematics content and methods of teaching; (3) a focus on helping candidates learn to use specific practice(s) and tools that are then applied to clinical experiences; (4) candidates' opportunities to study the local district curriculum; (5) a capstone project (portfolio done in classrooms with youth) an (6) programs percentage of tenure-line faculty, which the researchers view as institutional investment and program stability (p. 40).

Although these features have been identified, Darling-Hammond (2010) discusses that not all preservice programs agree on what constitutes critical knowledge(s) necessary for the professionalization of future teachers and how to best prepare them for their practice(s) . This in combination with the limited focus in research and teaching circles on programs which are not well (highly) ranked or highly investigated by teachers and researchers. I argue that this is a limitation in my study.

I focus my work in this dissertation on a highly ranked teacher education program in the Midwestern United States (according to U.S. News and World Report rankings) which I will call Midwestern Research University (henceforth referred to as MRU). My study participants are in MRU's elementary teacher education program. Because this program is highly investigated and to some extent faculty, researchers, and graduate students (in addition to undergraduate students) work arduously to create frameworks of coherence within its courses, this constitutes a power differential between the institution I did this dissertation on and the possible generalizations that can be made to other programs or science methods courses. I particularly look at a science methods course that focuses on centering youth and community knowledge(s) and practice(s) at the forefront of their teacher education. This focus on youth in science methods is new in this program and is typically understudied in preservice teacher education programs more broadly.

Because of how teacher education programs have varying goals (within programs and across programs) in the ways they view teacher education (Darling-Hammond, 2010), noting these various goals can impact the ways classroom teaching practice(s) are developed. Cochran-Smith and Lytle (1999) argue that the teaching profession is forever tied to the purposes of schooling and educational change. These are driven by re-defined conceptions of policy, research and practice. These re-definitions make it difficult to agree on a specific set of practice(s) that constitutes effective teaching—especially if looking at them through a lens of culture. Although teacher education programs aim to advance teacher learning at various stages of practice so that they are prepared to enter the classrooms they will teach, teacher learning is known to occur at various levels of learning to teach. Making sense of these different school cultures and environments as they learn to teach support this challenge (Cochran-Smith & Lytle, 1999).

In this dissertation, I localize these re-definitions of policy, research, and practice in the communities and schools where PSTs learn to teach because that is where the interaction of varying people and cultures (Bryan & Atwater, 2002) occurs as they learn to define and redefine the youth-centered practice(s) they imagine and enact. This focus can help PSTs in learning specific practice(s) and tools necessary to support youth in their particular field experiences (Darling-Hammond, 2010).

Because practice(s) are an important part of the conversation around supporting PSTs understand the culture of science, their classrooms and the youth they will teach, it is important to delve into what practice(s) mean in teacher education.

Practices in Teacher Education

Practice(s) are the beliefs, ideas and methods teachers bring to their classrooms and are currently an important area of study in preservice teacher education (Windschitl et al., 2012).

The most successful teachers have a repertoire that is “complex, relational, grounded in deep understanding of subject matter, and adaptive to learner’s needs” (Windschitl et al., 2012). In teaching, practice(s) are never neutral, and are inherently tied to culture since there are varying contexts and social situations. Teacher learning and developing practice(s) from youth perspectives calls attention to how science is deeply rooted in the histories and geographies of young people, where science involves broader social and community concerns (Windschitl & Calabrese Barton, 2016).

The concerted attention in teacher education (and science teacher education) to develop and support practice(s) that are at the core of teaching and are ambitious in nature are necessary and important (Ball & Forzani, 2009; Windschitl et al., 2012). However, in their paper, Windschitl and Calabrese Barton (2016) conclude that ambitious science teaching (as one type of teaching practice) research has not systematically taken up equity-related concerns and this is a large gap that needs to be addressed in how/what ways PSTs develop these equity-related practice(s).

In order to address these equity-related concerns in developing practice(s), I argue that there needs to be a generative and iterative focus on PSTs development of practice(s) towards how they take up on youth knowledge(s) and practice(s) over time, creating more equity-oriented spaces in their classrooms through years of expert teaching. By viewing classrooms as conceptual spaces, and the generative uptake of how youth repertoires of practice (Gutiérrez & Rogoff, 2003) shift classrooms local practice(s) over time, then PSTs learn to recognize how they should implicate themselves in those spaces and recognize the power inherent in classrooms between teachers and their youth, and youth with each other to produce a more youth-centered and equity-oriented view of science in their classrooms.

Hence, this view of practice(s) is not high-leveraged or ambitious, but generative in their becoming where I want to (re)center the sociopolitical view in science education (Rodriguez, 1998; Tolbert & Bazzul, 2016). This sociopolitical view politicizes and foregrounds large structural inequities over space and time and that examines how race, class, sex/gender, ability dynamic play a role in the colonizing practice(s) of science education in classrooms with PSTs as beginning science teachers and the youth they will teach. In the next section, I discuss a new view of how to support these youth-centered, equity-oriented teaching practice(s) in science teacher education.

Youth-Centered, Equity-Oriented (YCEO) Science Teaching Practices

Faith's beginning vignette explained one example of how views of youth science learning can better support how not only youth see themselves and take action on social/historical/political problem spaces in their communities, but how this plays out in ways teachers support youth in their teaching in ways that center youth's views and purposes of science.

Previous discussions on the culture of science, goals for science teaching, and teaching practice(s) centered the importance of how youth knowledge(s) and practice(s) are inherently tied to all goals in science education. In previous sections of this literature review, I discussed how practice(s) are never neutral and are very much tied to culture (in whose knowledge(s) counts and for what purposes and what practice(s) are important to participate in the culture of power). These are ever more important depending on where this culture functions within contexts and social situations. I argue that PSTs learning and developing practice(s) from youth knowledge(s) and practice(s) calls attention to how science is deeply rooted in the histories and geographies of young people, where science involves broader social and community concerns.

Hence in this section, I discuss that these sociopolitical views in science teacher education should be shifted to supporting a youth-centered (by supporting the cultural, historical, political backgrounds/experiences of youth) and equity-oriented (that they focus on valuing and supporting the perspectives and that science does not continue to reproduce hegemonic knowledge(s) and practice(s) that continues to isolate youth from culturally diverse backgrounds) science teaching.

In conceptualizing youth-centered, equity-oriented (*YCEO practices)* in science, the focus must be on: (1) the “culture of power” (Delpit, 1988) that exists in society and that its inequities are also reproduced in science teaching and learning; (Calabrese Barton & Yang, 2000), 2) teacher learning that is deeply connected to the histories and lives of youth; (Ladson-Billings, 2001; Nieto, 1999), 3) recognizing youths’ funds of knowledge and repertoires of practice (Gutiérrez & Rogoff, 2003; Moll, Amanti, Neff, & Gonzalez, 2006) can be legitimate resources for science learning, and 4) how teachers recognize the ways youth histories, lives, funds of knowledge(s) and repertoires shape the disciplinary knowledge(s) and practice(s) of the (scientific) community in which they are in.

These practice(s) are also concerned with shifting stereotypical and essentialist notions regarding the underrepresentation of minoritized youth in science to one that recognizes and positions youth as social change agents (Gutiérrez et al., 2017). At the same time, this approach asks teachers to recognize the education debt and that educational outcomes are inherently tied to ways youth are minoritized, historicized, politicized, racialized in society and in in their schooling (Ladson-Billings, 2006). In taking an assets-based, disruptive stance, I am not just seeking for teachers to engage in these practice(s), but that they engage in these practice(s) to recognize and disrupt systems of oppression, an idea critically needed in teacher education.

It is important to say that by developing YCEO practice(s), PSTs can be supported in a more robust use of generative practice(s) in science teacher education. This element supports reflexivity in practice(s) while also understanding the social, historical, political underpinnings of youth and communities, but also the historicity of science teaching and learning and its effects on minoritized youth. The next section discusses how developing practice(s) through conceptual spaces can support a new way of developing youth-centered, equity-oriented teaching practice(s) in science education.

Developing Practices in a Conceptual Space through Pedagogical Imaginaries

One of the goals for this dissertation is to understand how spaces can become important in supporting PSTs in developing imaginaries that can be shaped and re-shaped over time in support of more youth-centered, equity-oriented science teaching. A study that might help in understanding the ways in which gaps in knowledge(s) and practice(s) between PSTs and youth are addressed is by looking at how pedagogical imaginaries gives voice to the seen, unseen and the cultural understanding of learning can be engaged with simultaneously (Dominguez, 2015). Using the idea of the pedagogical imaginary, teachers can create a conceptual space of developing where they can redefine rules, divisions of labor, ways to move across tensions in what they can see in their practice(s). Hence, while being able to engage in the pedagogical imaginary, teachers must use strategies that allow them to produce consequential shifts in their pedagogy, such as understanding the in-the-moment incorporation or removal of more and less effective practice(s) from their repertoire in ways they can see in their classroom (van Es & Sherin, 2002).

In his study, Dominguez (2015) followed five individuals during their semester long teaching experience where the novices were to develop experiences for classroom practice. The weekly seminar had a widely open-ended curriculum where teachers were engaged in coaching practice with novice educators in way that would help them understand curriculum and cultivating and deepening conversation and sense making around challenging moments in their practices.

This dissertation adds to the literature is by unpacking ways PSTs can learn to teach by starting where the youth are –not just around the ideas and knowledge of science they hold—but rather the problems and perspectives of community and how they view these alongside their science learning experiences. This generative unpacking of youth knowledge(s) and practice(s) also includes critical connections between classroom and culture—and how the interplay of these shape the scientific knowledge(s) and practice(s) that is upheld within the classroom community. More frameworks are needed to support pedagogical imaginaries in teacher education that support a generative shaping/re-shaping of views of youth through practical realities and emotions involved in the ways youth and teachers make sense of their interactions. Especially how local practice(s) and spaces/places and the cultures within them shapes the enactments of these imaginaries. In the next section, I delve into literature on teaching in school science and how theorizing YCEO practice(s) can add to the literature.

Teaching in School Science with an Eye Towards Enacting YCEO Practices

The culture of science will always be influenced by the teaching practice(s) that are acted upon in that culture. It is important, however, to understand how/in what ways cultural practice(s) in teaching in school science has developed discursive, acquisition, identity/agency, and inquiry-based practice(s) in the classroom. Particularly in how these have been traditionally upheld in the culture of science teaching.

School science focuses on the acquisition of transmitted knowledge(s) and general processes of scientific practice (Lemke, 1992; Newton et al., 1999; Rudolph, 2002). Lee and Roth (2003) argue "current practice(s) of science education focus on youth' conformity to authoritative knowledge(s) and scientific discourse that are relevant to research scientists" (p. 404) The lack of connection to the world in which individuals live and interact isolates scientific knowledge(s) and practice(s) from individuals lived experiences and localized concerns (Gruenwald & Smith, 2008).

In its traditional sense, science education is viewed as the transmission of "authoritative knowledge(s)" which has reproduced hegemonic cultural practices and ways of knowing and failing to recognize and even marginalize cultures and practices that fall outside of this authoritarian knowledge (Bang & Medin, 2010). In some cases, youth are asked to assimilate to the scientific practice(s) of the intellectual elite (Calabrese Barton & Yang, 2000). Calabrese Barton and Yang (2000) argue that this can lead to "[youth learning] that boundaries exist which separate who is and who is not capable of science" (p. 876). These definitions and practice(s) dominate much of the science education in classrooms in which these operate today. However, there must also be an acknowledgement that *The Framework/*NGSS attempt to push back on this transmission of authoritative knowledge and of learning science. There are problems with this transmission model of authoritative knowledge, but taking a critical stance, the issues are not just in how the transmission model functions but the systematic power structures that that take shape in local practice(s) . These include arguments from how school science reproduces western epistemology, the limited uptake of cultural contributions of youth and positioning and minoritizing youth who are not culturally part of the dominant groups ending with the goals for scientific literacy (discussed previously in this review).

Several researchers have theorized how certain discursive practice(s) support evidence based reasoning and successful engagement in evidence construction, such as making claims based on reasoning and evidence that relate to variables being observed. This is often made in response to a question posed and requires an investigation, which the student must answer (Zangori, Forbes, & Biggers, 2013). However, sometimes these discourse patterns lead to, for example, initiation-response-evaluation (IRE) (Lemke, 1990). With IRE, the teacher initiates a question, the student responds, and the teacher immediately evaluates if it is correct or incorrect. This type of discourse move has led to widespread belief that teachers not only control student-initiated discourse, but responses evaluated further lead to taking up on disciplinary authoritative knowledge(s) and maintaining control of the classroom (Bleicher, Tobin, & McRobbie, 2003).

Making sense of these discourse patterns are important in how and what ways developing teachers may or may not fully support youth' cultural discursive practice(s). Some studies attempt to understand how discourse patterns are related to youth' ways of identifying with and in science.

In one study related to this participation, Brown (2004) studied how ethnic minority youth who participated in the cultural and discursive practice(s) of high school science were in constant intrapersonal conflict due to taking up on this "transmission of authoritative knowledge(s)" (Bang & Medin, 2010). The author engaged in a discourse analysis to understand youth' discursive identity development. He found that youth demonstrated *differential appropriation* of science discourse through four discursive identities ranging from avoiding scientific discourse to youth incorporating scientific discourse as their primary discourse. In his discussion, the author argues that it is the responsibility of science educators to seek to identify ways which seek to make these scientific discourses explicit to youth. Specifically, teachers should provide instructional practice(s) appropriate for scaffolding youth into developing a mastery of science discourse. Although, I agree with the former argument, the latter argument is one that focuses on assimilation and this can create an alienation of youth who culturally do not associate with science (Calabrese Barton & Yang, 2000). YCEO practice(s) allows to shift discursive practice(s) towards enacting purposes and views of science such as those embedded in youth experiences or community problems and making that the center (e.g. in planning the lesson) rather than the explicit scientific discourse embedded in *The Framework/*NGSS.

Building on the notion of discursive identity, Carlone (2012) questions how youth productively take on the study of language and culture in science. For example, "who are individual youth becoming in the setting?" in contrast to "who are youth obligated to be in a setting?" In her paper, she describes Mrs. Sparrow's class, where youth in the class describe what it means to be a science student. Students aligned with historically enduring meanings of school science such as a person who "answers the teacher's questions correctly, knows a lot of facts, or pays attention and uses big words." (p. 14). Although important to know, this type of scientific identity may be prescriptive and removed from youth' lives and personal goals for science learning. Carlone's (2012) study, the girls of color in Mrs. Sparrow's class all described liking science, but they characterized themselves as not being smart like the science youth who knew the "big words." (p. 14).

Hence, outcomes of school focused on narrow definitions of what it is to know and do science don't align with learning in everyday life where outcomes might be defined through various forms of participation and how knowledge(s) and practice(s) develop. Instead, school science often leads to youth "acquiring a sufficient number of facts and understandings to ensure adequate performance on exams, both classroom and standards-based" (Sadler, 2009, p. 7).

Narrowly defined school outcomes can isolate school science from everyday life by limiting the opportunities for the development of hybrid spaces, or places in which science and everyday life come together. As Eisenhart, Finkel and Marion (1996) argue, “schools and teachers are to be held accountable for knowledge(s) but not for its situated or future use” (p. 268).

Other studies have focused on how youth identify with sciences and how these identities can shape the culture or views of science that were valued by teachers and peers.

Carlone, Haun-Frank, and Webb (2011) looked at the impact of intended outcomes on student perceptions of science and identities assumed while doing science in their study of two fourth-grade reform-based science classrooms. Although each classroom had implemented the same reform-based pedagogy, the intended outcomes or what it meant to be scientific were much different in each space. One classroom had very normative school outcomes where being “science people” meant that one “figured things out for themselves and did not necessarily get ideas from others or productively share ideas with others” (p. 469). Student identities were valued when youth independently investigated and came up with the right answer or gained the correct knowledge(s). The youth who came up with the “right answers in the right way” were viewed by peers as “scientific people.”

In contrast, the learning outcomes of the second class were focused on the social process of “being scientific”. The authors argue, “doing science in this class meant, in part, working with, sharing ideas with, asking question of and listening to a partner or group mates” (Carlone et al., 2011, p. 473). A scientific person was not positioned as one that just got the right answers but was part of the process in developing ideas and asking questions that led the class to develop different scientific understandings and practice(s).

Carlone et al. (2011) found that although youth in both classes reported an overall interest in science, youth in the second classroom self-identified as “smart science people” at a much greater frequency. In fact, data from the first classroom revealed not only did many youth not identify themselves as one of the smartest science youth, but “46% (all Students of Color) did not identify any characteristic shared with smart youth” (p. 462). Carlone et al. study reveals how the outcomes and valued identities of the classroom influence the ways in which student view the value of their participation and divide who is and isn’t capable of being scientific. When only normative outcomes are valued, many youth are denied access and unable to take on identities of the “smart science student” and the process of doing science.

If science educators are seeking to transform the practice(s) inherent to not only the culture of science, and the practice(s) that support science teaching but also substantially reforming how/in what was science classroom as local practice(s) function, there must be a challenge to these discourse(s) and practice(s) and ways classrooms continue to value authoritative, hegemonic practices that has historically disenfranchised and minoritized youth in their science learning. Theorizing a way to understand how PSTs develop imaginaries and enact YCEO practice(s) in their field experiences is one way to push this work forward.

Chapters three, four and five of the dissertation focus on developing a theoretical framework (chapter six) across the findings in the three chapters that looks at how youth (chapter three), PSTs during a science methods course (chapter four) and enactment of PSTs views of YCEO practice(s) in local classrooms (chapter five) support an initial view of how YCEO practice(s) in science education look like.

More specifically, chapter three also looks at *counternarratives of youth meaningful science learning* through the co-constructed multimodal cases of three youth who participated in an after school green energy program in Great Lakes City. Chapter four then focuses on how a methods course supports PSTs initial developments of pedagogical imaginaries in support of types of YCEO practice(s) as they learn to generatively take up youth knowledge(s) and practice(s) in their methods courses. They do this by grounding their field teaching communities in tandem with their own developing views of science teaching. Chapter five then follows three PSTs as they learn to enact their views of YCEO practice(s) during an engineering design unit in their field teaching classrooms and how these enactments were shaped by local practice. .

Making science a civil right is long overdue and where transforming future teachers' habits of minds in equitably-consequential ways should be a goal for science education. This dissertation is my attempt to conceptualize YCEO practice(s) as a new method of learning to teach centered on youth knowledge(s) and practice(s) in science teacher education.

CHAPTER THREE:

YOUTH COUNTERNARRATIVES OF THE CULTURE OF POWER IN SCIENCE

I want to say my name is AD. I am my "super me" because I am my alter ego…. In school we learn things and then we do tests on what we learn and then we move on. We really don't get the time to see what we're interested in. I try to do things outside of school that let me explore my interests, like making things. I also try to connect my experiences from school, or sometimes what I learn with bigger messages like what I am learning in my history and biology class, which right now is interesting to me.

Introduction

AD[5], a 14-year-old Black Latina student, is a maker, poet and YouTuber. In her YouTube videos, she documents her educational experiences, love for making and writing poetry through her evolutionary trajectory from middle-school to high school in Great Lakes City, Michigan.

In the after school green energy program at the Community Center of Great Lakes City, AD created a duct-tape thermometer tie for her father. The problem space began when AD was a child and her father--her family's sole caretaker--lost his white-collar job after being hospitalized without notice. This experience led to economic, educational and unexpected consequences in AD and her sibling's lives. In her opening vignette, she discussed that she is her own "super me." Her identity as a "super me" came from viewing herself as her own alter ego—one who has had to find ways to succeed and survive economically alongside her father.

As she participated and worked with me in the after school green energy club, AD shared with me deep narratives regarding her schooling experiences. Particularly, she told me how challenges in her life, and those of her community members and the experiences to overcome them, were *counter* to the narratives told about AD in her schooling experiences. AD challenged

[5] Pseudonym

how her schooling experiences in science and engineering did not connect to her life outside of school. To AD, science and engineering were dehumanizing subjects. They lacked personal connections, and she did not see them as changing, evolutionary beings. For her, the term evolution is an ontological becoming, meaning that as time goes on, views and purposes change as one gains new perspectives. Given the settled nature of expectations for science learning (Bang & Medin, 2010), most youth's educational, home, community experiences are not seen as valuable resources in their learning. In our work together, we discussed how to connect these pieces to larger, systematic problem spaces where historically, Youth of Color, were being continuously minoritized and pushed to the bottom of educational opportunities.

Over time, this relationship grew into a multi-year co-mentoring relationship. AD taught me about experiences in her life, so I could share with others (e.g. teachers, PSTs , other science teacher educators) as a researcher and I discussed my views and experiences in my schooling relationship as well.

This paper engages in a longitudinal critical ethnographic case study analysis of three youths' science learning as evidenced by their digital multimodal artifacts of science learning over time. In this paper, I argue that youth, when discussing these counternarratives of science and engineering learning open up to ways their learning expanded over space and time bringing in multifaceted and multi-layered learning experiences that can serve as learning opportunities for meaningful others. These deep and rich stories of Faith, AD and Christopher's experiences are illustrative of how youth push back against dominant narratives of the ways the culture of science has been reproduced and taught in schools, especially those stories told about them and their science learning. The research question(s) I investigated are:

1. What *counternarratives of the culture of power in science* and meaningful science learning experiences do the youth describe in their co-authored multimodal artifacts of science learning?
2. How do *counternarratives of the culture of power in science* shape the ways the youth want to see their learning by meaningful others (e.g. teachers/PSTs across space and time)?

Theoretical Frameworks

Counternarratives to the Culture of Power in Science

While there is a renewed call for science education research to take up cultural, socioeconomic and sociopolitical structures and equity-related concerns, there remains limited conceptual tools for investigating these structures from the perspective of power and privilege. Achieving equity in science education is paramount in our time, but how might science educational experiences be designed to be more equitable in its teaching, and how is it known, "what science and for whom?" (Herrenkohl & Bevan, 2017, p. 519). In their paper, Herrenkohl and Bevan (2017) discuss:

> Science is one of several important epistemological and disciplinary tools for achieving varied social ends; in particular, it's evidence-based ways of knowing can help young people think and act across multiple, contexts, whether in exploring local community issues, making the case for particular ideas or strategies, or reimagining and designing the world around them (p. 517)

Teaching in-school science has traditionally involved the acquisition of transmitted knowledge and general processes of scientific practice (Lemke, 1992; Newton et al., 1999; NRC, 2007; Rudolph, 2002). This transmission of authoritative knowledge(s) has led to "settled expectations" in science (Bang & Medin, 2010). Settled practice(s) can include focusing on teaching science content through what is valued in science education or positioning youth in ways that work against their engagement in meaningful science learning (Bang & Medin, 2010). AD's vignette reminds us of the settled nature of science classroom learning.

One of the arguments related to equity in science education is how language and settings where science teaching and learning occur can shift the ways frames of equity have been historicized or politicized (Philip & Azevedo, 2017). By historicizing and politicizing views of equity, Philip and Azevedo (2017) discuss connections between the goals of equity in science teaching, to more systematic impacts of science as a way to maintain global dominance. Particularly in that science education has become "a moving target" (p. 526) for those in positions of power where goals of science education have shifted over time in order to maintain power and authority and global dominance.

Historically and politically, equity in science has been linked to supporting inclusion of minoritized groups as a way to increase human capital in an effort to maintain U.S. global dominance across scientific, technological and economic lines (Philip & Azevedo, 2017). However, this focus does not unpack the diversity and changing relations of power in society (political effects and minoritization of diverse groups) and how this type of view maintains a culture of power in science (Calabrese Barton & Yang, 2000; Delpit, 1988). Recent strides have been taken to make better sense of how this historical and political view of equity can be a centerpiece of science teaching. For example, *The K-12 Framework for Science Education* has framed equity and different discourses relevant to what is important in K-12 in-school and out-of-school settings (NRC, 2012). However, much of these discourses on equity disregard how spaces, especially classrooms, and the science learning that takes place and for whom are never neutral.

Culture of power. The "culture of power" in science (Calabrese Barton & Yang, 2000; Delpit, 1988) is an important lens for understanding how to challenge traditional notions of what constitutes learning and expanding notions of how to take up equity related concerns in science education. For example, let's take the case of Miguel in Calabrese Barton and Yang's (2000) piece. The authors describe Miguel as "having been a proficient herpetologist since his days in the Boys Scouts, neither his parents nor his teachers drew on this strength and encouraged him to pursue science as a viable school activity or even a career" (p. 873). Miguel's experiences being tracked out of science and then his own experiences through making sense of his educational experiences, affected how he was unwelcomed/denied the tools in connecting his goals and pursuits with science (Calabrese Barton & Yang, 2000). In this case, Miguel was not provided the opportunity to succeed in the culture of power in science education even though he was engaging in scientific work. Many years later, Miguel's experience in the 2000 piece still continues to be the experience of so many youth today. Not only do youth describe how the culture of power functions in their own lives, but they are aware of the effects that this will have on them and their communities over space and time.

Delpit (1988) describes the aspects of power related to the culture of power as the following: (1) issues of power are enacted in classrooms; (2) there are codes or rules for participating in power, that is, there is a culture of power; (3) the rules of the culture of power are a reflection of the rules of the culture of those who have power; (4) if you are not already a participant in the culture of power, being told explicitly the rules of that culture makes acquiring power easier; (5) those with power are frequently least aware of --or at least willing to acknowledge(s)—its existence. Those with less power are often most aware of its existence (p. 282).

Calabrese Barton and Yang (2000) discuss Delpit's (1988) aspects of power including "making the rules for the culture of power explicit" and "those who are not familiar with the culture of power will lack opportunities for upward mobility, be perceived as deficient, inferior and disadvantaged, and be viewed as the cause of society's problems" (p. 874). However, there is also another important learning piece related to Delpit's argument in number five. She argues that *those with power are less aware of and least willing to acknowledge(s) the existence of such power, but those with less power are most aware of its existence.* This understanding is critical in relation to understanding how science education knowledge(s) and practice(s) have been culturally reproduced and settled (Bang & Medin, 2010), especially in white supremacist, patriarchal, heteronormative, capitalistic and imperialist (Hooks, 2004) ways which have benefited and perpetuated a certain class of people into science and scientific careers.

Youth, especially minoritized youth, who have experienced the effects of culture of power, ***know*** how this type of power functions to oppress them in their lives. Not only are they aware of it, they know that there are systems in place that function to maintain social and economic power over them. AD, Faith and Christopher who participated in this piece know the racial, classist notions associated with being welcomed into the culture of power of science.

Calabrese Barton and Yang's (2000) discussion in their piece reflects important points related to *why* youth may be left out of the culture of power. As they note, some scholars believe that youth should take on the discourse of the culture of power as way to function within it (e.g., NGSS). Critical of this stance, they argue that this is deficit oriented because it implies that youth must "rise up" from poverty towards attain educational achievement. I agree with this critical stance, and further develop it, by taking a critical view of the culture of power. Here I focus on changing cultures within institutions in order to support youths' cultural repertoires in critical ways. Race, class, gendered and cultural power dynamics and how they have limited opportunity for minoritized youth have been documented in science education research (Calabrese Barton, Tan, & Greenberg, 2016; Herrenkohl & Bevan, 2017; Philip & Azevedo, 2017; Sheth, 2018) but the role of counternarratives (as part of Critical Race Theory) as a lens to challenge the dominant ideology inherent in science knowledge(s) and practice(s) from youth voice is understudied and critically necessary.

This perspective adds onto work previously done in-school and out-of-school settings that upholds youth's knowledge(s) and practice(s) in science and in what ways discourses and cultural repertoires of youth are central to changing local practice(s) in support of youth lives and social futures (Calabrese Barton et al., 2016; Nazar et al., 2017). Focusing on building from youth knowledge(s) and practice(s) in science helps us better answer: what science and for whom?

Critical race theory. To better understand ways youth knowledge(s) and practice(s) can shift systematic racial, classist and gendered institutional power structures in science education, I look at Critical Race Theory (henceforth referred to as CRT) as one lens for engaging this kind of work. Matsuda (1991) describes CRT as "the work of progressive legal scholars who are attempting to develop a jurisprudence that accounts for the role of racism in American law and that work toward elimination of racism as part of larger goal of eliminating all forms of subordination" (p. 1331). CRT advances and foregrounds the role of race and racism as part of a larger goal of opposing or eliminating other forms of subordination related to gender, class, sexual orientation, language and national origin (Matsuda, 1991). In education, CRT seeks to understand perspectives, methods, and pedagogies (Solórzano, 1997; Solórzano & Bernal, 2001) that "identify, analyze and transform the structural and cultural aspects of education that maintain subordinate and dominant racial positions in and out of the classroom" (Solórzano & Yosso, 2001). CRT has five central tenants which include: (1) the intercentricity of race and racism with other forms of subordination; (2) the challenge to dominant ideology; (3) the commitment to social justice; (4) the centrality of experiential knowledge(s) and (5) the transdisciplinary perspective (Solórzano & Yosso, 2001). For the purposes of this argument, I will focus on two of these central tenets: the challenge to dominant ideology and the centrality of experiential knowledge.

The challenge of dominant ideology states that CRT challenges traditional claims that educational institutions make towards being colorblind, race neutral and equal. Philip and Azevedo's (2017) work is a reminder of how a focus on colorblind, race neutral and equal approaches are still existent in science education. Equity in science is viewed as a focus on "fairness" and "equal treatment for all" which is a colorblind approach to race, and "rein-scribes" inequities when it fails to address the historical, social, political, and economic contexts that have differentially afforded or limited opportunities to various groups" (p. 526). These claims camouflage for the self-interest of groups with power (Solórzano & Yosso, 2001). CRT methodologies challenge white privilege and rejects notions of neutral and objective research which at the end silences and distorts epistemologies of People of Color (Delgado Bernal, 1998).

When discussing epistemologies of People of Color, it is vital to centralize their experiential knowledge(s) in education. CRT recognizes that experiential knowledge(s) is legitimate and that drawing explicitly from these lived experiences including storytelling, family histories, biographies, chronicles and narratives allows to challenge traditional research paradigms and theories used to explain experiences of People of Color and exposes the silence and distortion done onto these communities. Instead the focus is on their racialized, gendered and classed experiences as a source of strength. I not only look at the youth stories in this piece as a source of strength, but I also view them as a source of change to challenge these dominant ideologies inherent in other institutions (e.g. preservice science teacher education).

Counternarratives have been used in educational research to name how racialized experiences have been positioned as inferior to majoritarian narratives in ways that limit educational opportunities. CRT's centrality on experiential knowledge(s) of minoritized communities to challenge dominant ideology can be an important lens to understand the framing of *counternarratives of the culture of power in science* in this chapter. This view can become one way to understand the role of race, gendered, and classist power dynamics are existent in youth's science learning. Particularly because AD, Faith, and Christopher's—all Youth of Color—experiences with science are deeply entrenched in cultural issues dominated by race and racism in science education (Ball & Tyson, 2011; Mensah & Jackson, 2018; Mutegi, 2011; Parsons, 2014). I am not explicitly focusing on only race in regard to what counternarratives are told in this paper, but rather emphasize how counternarratives can become critical in challenging the culture of power evident in their science learning experiences. Hence this is why I focus on the culture of power because these include how race, class and gendered notions are inherent—and often hidden—in science teaching and learning.

Critical Race Theory in Science Education

In the discipline of science education, few studies take on CRT as an analytical lens for understanding experiences of minoritized youth. In an attempt to change this, Fraser-Abder, Atwater, and Lee (2006) noted that a National Science Foundation (NSF) session was organized to explore new ways to answer questions of representation in science education which included a focus on new avenues for research in critical race theory, transcultural theory and economic theories.

The influence of CRT in science education, though limited, involves 1) how youth are positioned in classrooms, 2) how recognition of those that hold power in dominant positions (e.g. teachers) shape the ways the culture of power is reproduced in science education, and 3) CRT as a lens to examine science teacher education.

Examples include: Science education research using a CRT lens has found that minoritized Youth of Color do not receive the same opportunities in science as white youth in the same classrooms (Parsons, Tran, & Gomillion, 2008; Tate, 1999; Yerrick & Johnson, 2011). One study by Yerrick and Johnson (2011) found that there is specific cultural knowledge(s) needed by white male teachers to teach an all-Black earth science class in culturally responsive ways. The authors found that when the knowledge(s) needed to teach culturally diverse youth is not present, inequitable science instruction could be reproduced in these spaces. This research showed that by not recognizing the cultural contributions of Youth of Color, science learning can become racist.

A second influence of CRT in science education involves the recognition of power between those that hold power in dominant positions and how counternarratives of agency (using science to take action) can help better understand desire for success in science education (Basu & Calabrese Barton, 2007). Mutegi’s (2011) work on unpacking how Modern Western Science (MWS) has been epistemologically reproduced in classrooms showed that this epistemological focus in science alienated youth whose ways of knowing and being were not representative of the MWS view of science learning. In another study, Rodriguez (2011) focused on how eurocentric frames and practice(s) are also reproduced in science classrooms and can also become alienating for Youth of Color.

In regard to science teacher education and CRT, Mensah (2011) found that PSTs are not prepared to teach culturally diverse Youth of Color. In another study, by the same author, Mensah and Jackson (2018) found that whiteness as property, a major CRT tenant, manifests itself through curriculum, structure and pedagogy in science teacher education programs which alienates and excludes future Teachers of Color in science. This has important implications on who can become science teachers and especially for Youth of Color.

Although this chapter is one way to understand how minoritized Youth of Color discuss meaningful science learning experiences through a lens of counternarratives of the culture of power of science, more research is needed in science education to explore intersectionalities between how CRT, transcultural issues and economic/social impacts affect minoritized student's success in science.

In the next section, I discuss the second theoretical frame of this paper, expansive learning.

Expansive Learning

This study is also grounded in expansive theories of learning (Engeström & Sannino, 2010) in which "learners are involved in constructing and implementing a radically new, wider and more complex object and concept for activity" (p. 2). More specifically, it puts the "primacy on communities as learners, on transformation and creation of culture, on horizontal movement and hybridization, and on the formation of theoretical concepts" (Engeström & Sannino, 2010, p. 2).

Particularly this theoretical framework places great emphasis on horizontal movement and its hybridization, or novel combinations of different repertoires of knowledge(s) and practice(s) as individuals move ideas and practice(s) across these spaces (Engeström & Sannino, 2010).

Gutiérrez's (2012) work on expansive learning also calls attention to movement as central to expansive learning. She suggests that attention ought to be paid to two forms of movement--the vertical (e.g. novice to experience within a domain) and the horizontal (across communities of practice(s)) --and the intersections among them. Here, movement refers to the ways in which ideas, tools, and practice(s) are re-authored and re-purposed towards new possibilities for becoming in practice(s) across settings and over time. The horizontal movement of learning often entails hybridizing or transforming ideas, practice(s), and tools acquired from different places toward the creation of new meanings and identities (Gutiérrez, 2008, 2012; Tan & Calabrese Barton, 2012). It also promotes the creation of new modes of engagement in cultural practice(s) that challenge the normative way of participating in practice(s) within certain communities (e.g., science classrooms, or STEM) (Tan & Calabrese Barton, 2012). As learning takes place, new activity structures are produced as vertical and horizontal dimensions interact, leading to new forms of activity. Gutiérrez (2012) describes these new forms of activity as dynamic forms of hybridity that emerge as tensions and contradictions, arise within and between activity systems, transforming how and why these systems overlap.

For example, in a piece by Nazar et al. (2017), Faith, the focus youth of the study and who also is part of this piece, was able to hybridize her community and science practice(s) in ways that allowed her cultural ways of knowing and being to be legitimized by STEM and community experts in creating her FANcy Hat. Important to her Faith were how her cultural knowledge(s) and experiences were legitimate resources for engaging in/with STEM (Gutiérrez & Calabrese Barton, 2015). However, challenges of her work in and within the activities of STEM at times created *epistemological contradictions*, these became important sources of negotiation between community knowledge(s)/practice(s) and STEM knowledge(s)/practice(s) . These negotiations allowed her to navigate and cross the boundaries of STEM in different settings, learning and moving across spaces and time (Nazar et al., 2017). This expanded concept of learning encourages us to view individuals as engaging in the ongoing authoring of new selves, knowledge(s), objects by means of diverse practice(s) or tools.

This type of learning also challenges other participation and acquisition-based approaches which depict learning primarily as a one-way movement from "incompetence to competence" (Engeström & Sannino, 2010) or how traditional school science is seen as transmission of knowledge(s) (Lemke, 1992). Nonetheless, horizontal movement and hybridization do not happen within or across neutral spaces. That is, one's learning is always situated in local practice(s) in relation to specific histories and context. When individuals--or in this case, Youth of Color--are allowed to make sense and see how their raced, classed and gendered experiences come in contradiction with the system in which these minoritizing effects operate, new forms of participation and engagement can be seen which create powerful counternarratives as practice(s) that give way to understanding youth's own repertoires of practice (Gutiérrez & Rogoff, 2003) in expansive ways.

Learning about Culture of Power through Expansive Learning

In summary, understanding *counternarratives of the culture of power in science* through a CRT and expansive learning frame makes visible the ways in which the culture of power operates in science education for Youth of Color over spaces and time. I argue in support of a kind of institutional shift that focuses on putting youth knowledge(s) and practice(s) in conversation with the people and places that affect Youth of Color's educational success. This means master narratives told of and about youth in regard to their K-12 learning and the ways Youth of Color engage in/with science must be challenged. CRT and expansive learning help me to challenge these institutional narratives by focusing on the histories, views and purposes of science through a frame of valuing counternarratives related to Youth of Color's engagement with/in meaningful science learning. The counternarratives that AD, Faith and Christopher co-developed in this chapter spans many years and are multifaced and intersectional in ways youth detail the movement knowledge(s), practice(s) and resources over space and time.

Institutions and the people/places that are complicit in the institutional reproduction of the culture of power in science need not only be educated in understanding youth counternarratives, but also systematically take up these counternarratives towards shifting practice(s) that uphold the knowledge(s) and practice(s) of minoritized youth in science education. This focus creates intersectional opportunities to address power and privilege in science rather than to maintain science's historical and political epistemic, methodological and ontological dominance over minoritized youth and communities. Institutions cannot change without knowledge(s) to change. Together, these frameworks are one way to understand how youth learn about and respond to systemic power dynamics in their lives, with and in STEM culture of science that is already known to be exclusionary and minoritizing.

Methodology and Methods

Critical Ethnographic Multiple Case Studies

I employed critical ethnography as my primary methodology for this paper because it is a humanizing methodology for conducting research for participatory critique, transformation, empowerment and social justice (Paris & Winn, 2013; Trueba, 1999). This methodology "blurs the lines" and exposes, critiques and transforms inequities associated with structures and labeling devices inherent to fundamental dimensions of research analysis that involves race/ethnicity and gender dynamics (Calabrese Barton, 2001). For example, in transforming and critiquing these labeling structures, the youth and I critiqued much of the systemic assumptions made about us as minoritized, People of Color. These co-constructed cases iteratively and generatively moved away from essentialist notions regarding our shared minoritization. Rather, we used the co-constructed cases to embed discourses important to each of the youth in ways that took up on movement of knowledge(s), practice(s) and resources over space and time.

Moreover, critical ethnography leads this study toward the goal of transformation (praxis) of social conditions or structures that have systematically disenfranchised minoritized youth. Ultimately, this type of methodology allows me to "politicize" the interaction between actors and the social structures, grounded in the belief that these relationships are never neutral.

Secondly, I employed a multiple case study approach because it allows me to understand a complex social phenomenon in relation to its context for multiple participants (Yin, 2004). Together with critical ethnography, these resulted in critical ethnographic multiple case studies. These case studies provide important learning from counternarratives youth shared—and co-constructed with me—revealing important historical and cultural practice(s) guiding participation, identity formation, and action taking in science in meaningful ways. However, given my focus on critiquing systematic assumptions related to essentialization based on cultural repertoires, focusing on multiple case studies allows me to understand how embedded discourses are different for each youth.

The case studies were constructed from several data sources and use multimodality as a powerful tool of communication. The wave of new and changing ways youth represents themselves, their families, communities and figured worlds, multimodality allows to see these representations in more intersectional ways. Miller and McVee (2013) discuss multimodal composing in the digital age as a significant way of making meaning and communicating of engaging youth and their audiences in purposeful representations of concepts.

Although multimodal composing is usually thought of as a classroom literacy learning tool, there is increasing attention to facilitating student use of multimodal composing in classrooms because it gives tools to purposefully communicate new ideas. Students can orchestrate music, narratives, and images, create and dramatize voice-overs, write and enact scenes, which put "things to work" (Miller & McVee, 2013). Also, multimodal composing allows to create a support social space for mediation, where there is purpose for embodied teaching and learning that draws upon the identity and worlds of youth (Miller & McVee, 2013).

For example, Hull and Katz (2006) wrote case studies on a multi-year digital storytelling project of how powerful multimedia, and multiple-modality literacies allowed youth to create autobiographical narratives about self, community society and their own sense of purpose. Supporting the use of multimodal cases through critical ethnography to present this research allows us to see multiple figured worlds, ideas, ways of knowing, being and expressions that youth feel comfortable with to tell others their story using these multiple literacies.

I view the outcomes of this researcher as much broader than this manuscript and the cases themselves. I have worked with youth to design research outcomes which matter to them, including Weebly pages where they showcase their work and want others to learn from. In addition, the youth have also presented their work in community settings to an audience of other teachers, parents, community members and have used this work to co-teach science methods courses.

Data Collection

Context. The study setting was Great Lakes City, MI [USA] an urban area hit hard by economic recessions and subsequent population decline experienced across the state (U.S. Census Bureau, 2013). Since 2012, the youth who are the focus of this study, AD, Faith and Christopher, have participated in the green energy program located inside the Community Center of Great Lakes City. The center supports approximately 2,400 youth from predominantly low income and minoritized backgrounds (ages 7-17) in personal development, homework assistance, and sports activities. This environment engages youth in playing, learning and having fun. While poverty and loss of industry often frame conversations about Great Lakes City, the youth who attend our makerspace are also quick to point out that Great Lakes City is a "close knit community" with "a lot of fun things to do and places to go."

After school green energy club. The after school green energy club is open to youth ages 10-15 and welcomes approximately 20 youth per year to work on engineering designs for sustainable communities (see Chapter 2 on discussion related to engineering for sustainable communities). In their engineering work, youth engage in the scientific practice(s) of identifying problems and designing solutions *for and with* community members that use green energy technologies (Calabrese Barton et al., 2016; Nazar et al., 2017). The program goal is for these designs to be locally relevant and of global importance, supporting the youth in developing deep understandings of science while also leveraging their expertise of their community to take action.

Each Tuesday and Thursday during the school year, club participants meet in a modest space dubbed the "club room." On Tuesdays, the youth participate in energy related investigations that include working to gain understandings of the relevant science concepts and practice(s). On Thursdays, the youth work with technology to create artifacts to share with peers and other community members about their energy related investigations.

The green energy club adopts a unique approach, engaging youth iteratively and generativity in making activities and in community ethnography as one approach to embedding local knowledge(s) and practice(s) into making or engineering design. Using the cultural tools of ethnography (e.g., collecting multiple perspectives by interviewing community members about safety issues in their community or observing and recording where bullying happens), youth move into community spaces to gain insights into the technological and social aspects of their community's problems. After collecting this data, they analyze and define these problems in their green energy club before developing design solutions, with the support of tools in the space. The program also offers a two-week summer intensive summer experience providing opportunities for youth to engage with other energy-related science experts in their community and state.

Phases of study. This study was done in two phases: *Phase One* (henceforth referred to as P1) and *Phase Two* (henceforth referred to as P2). P1 data collection took place as they created their engineering designs in the after-school club and the artifacts collected during this time. These include a thermometer tie (AD), an anti-bully cell phone application (Christopher) and a solar-powered fan hat (Faith). P2 was conceptualized a year later when the youth and I came together to understand what they learned from their designs which resulted in the multimodal case studies.

Originally, my plan was to conduct a one-hour post-design interview to understand youth's engineering learning as a result from their work in the after-school club. However, after each of the youth's interviews progressed, we began to discuss critical connections to high school courses they were taking that year. This topic became important since the youth were transitioning between middle school and high school. The differences between middle school and high school in teacher supports and the implicit focus on science content were noticeable to them as they interviewed with me. Because they always had a story to tell me regarding these science experiences in high school compared to the ways they experienced learning in the after-school program, we decided to continue meeting.

In addition, a lot of the discussions around the design work and the solutions they designed with their inventions involved using pictures and videos of their time in the after-school club. We used "data" from P1 to explain design choices and movement of ideas over the course of the design. Hence, we created "e-portfolios," or electronic portfolios of all their artifacts during the design year which were used to create the multimodal cases in P2.

Data generation. Data for P1 (2013-2014) were generated from artifacts, youth conversation groups, and video analysis capturing youth interaction with science/engineering and community experts at various stages in their design process for the design year (See Table 3.1). In addition, we had mid-course artifact interviews (December of school-year), feedback cycle day with engineering experts (twice during the year), final artifact interviews (May of school-year), researcher field notes (per session) as well as youth created multimedia showing progress on their design to community members and engineering experts (varies on youth need). Data for P2 (2015-2016) were generated from interviews of multimodal case construction, multimodal artifacts used from P1 design year to make sense of engineering design work through online case on www.weebly.com/youth, researcher field notes and observations.

Table 3.1:
Methods of Data Generation

Data Form	Specific Data Generation Strategy	
	Phase One P1 (2013-2014: Faith) (2014-2015: AD, Christopher)	*Phase Two* P2 (All Youth: October 2015- March 2016)
Participant Observation	After school green energy program; video recordings of twice weekly sessions and field notes (48 sessions, 72 hours) Green energy club community events (Feedback Cycle Day, Presentations at the Art Museum, Field trip to local college campus, presentation of design to school community, etc.): Video recordings of events and field notes (3 events, 6 hours)	Audio recording and field notes of interview and participant observation (15 sessions, 20 hours each student)
Conversation Group	As a way to debrief what was happening in the club as well as to plan for future activities (18 weeks, 36 hours) 6-week segment of the conversation group focused primarily on how and why youths shifted their design, what funds of knowledge(s) or STEM knowledge(s) youth drew upon or leveraged for their design, and how youths positioned themselves in engaging in engineering design process	Case study interviews and participant observation during multimodal case co-construction (15 sessions, 20 hours each)
Artifact Think Aloud	Allowing youth opportunities to talk about their engineering design work in detail (Twice during the year) Mid-year (December 2013; December 2014) – 3D Google SketchUp model of design, SketchUp notebook, and initial prototype End of year (May 2014; May 2015) Final prototype, sketch-up notebook, and movie	
Artifact Collection	Youth's SketchUp notebook, 3D Google SketchUp model of design, worksheets, prototype, movie, etc.	E-portfolios from P2 used artifacts collected during P1

Positionality and participants. As their P1 engineering design mentor, I worked with AD, Faith, and Christopher the creation of their engineering designs. Throughout our work meetings in the green energy club every Tuesday and Thursday, we had open conversations about schooling experiences related to bullying and other effects of classroom life. I also shared my experiences as a graduate student at a predominately white institution (PWI) which almost always ended with conversations around how we were collectively minoritized and oppressed in some way by our schooling experiences. Recent news about shootings and a focus on engaging politically through movements such #BlackLivesMatter, allowed us to further discuss how we wished systems of power positioned us differently as minoritized people by humanizing our existence.

In our conversations about race and my schooling experiences, since I am a white-skinned Latina, I oftentimes openly discussed how that put me in positions of power. I spoke about gang violence in my neighborhood in Passaic, New Jersey and that because of the color of my skin, I may have had opportunities that my other Mexican or Black friends didn't have. In other instances, we talked about how our teachers (collectively) would not take on our experiences and everyday lives as part of our learning.

The after-school space also allowed us to work together towards the goal of finding mutual trust. In my work as their mentor, I encouraged youth to share their epistemological, home, community and school expertise and views of such in critique of the broader systemic practice(s) done on them as they worked on their designs.

As the design year went on, I was in a point in my doctoral program where I wanted to do research on what I was observing at the club. At the end of the green energy year in 2014-2015, I asked AD, Faith and Christopher if they would let me interview them about their use of science and engineering practice(s) during the design year. I was interested in how their designs took up on the Next Generation Science Standards (NGSS Lead States, 2013) in the ways they designed their inventions and how this can inform science education as a discipline. The youth agreed, and we set up times to meet and interview together.

Christopher and Faith continued their work at the Community Center for this part of the research as they had better transportation to the club. AD could not go because she was working part-time as a babysitter to help her father with household bills as they were transitioning to a new apartment. She wanted to be part of the work, and I needed to find times around her schedule. We even created a special Facebook calendar to keep each other in the loop on our availabilities

Finding a time to go to the club together was very difficult, so to keep AD in the loop and to not exclude her story from my work, I decided to do home visits and work with her from her apartment. There were times when I picked up AD from school because she could not get to the bus in time to arrive to the meetings we planned. During these meetings with AD, I not only moved my computer, recording equipment and artifacts to her home every week, but we did not have internet access at her home. This limited my ability to access her e-portfolio from our research group's online cloud. I tethered my phone and used a phone plan to support our data uploads on Weebly, but oftentimes these technological difficulties gave us some open space to discuss ideas and perspectives that were not centered on the engineering work or design.

This work was essential to my methodological becoming because it taught me how my decisions as a researcher can shape who feels included in the work. Because working around these resources prompted AD and I to have a more personal relationship, we instead engaged in very critical conversations of her everyday practice(s) and schooling experiences which were many times were not related directly to the after-school club experience but learning over space and time in relation to what she was seeing in school.

The experience with AD in discussing views of science related to the after-school club and how these views changed as a result of entering high school is what prompted the idea of creating expansive views of youth science learning. I then took this experience in working with AD to Faith and Christopher, who also decided that they were interested in doing work that allowed them to debrief about school and schooling practice(s) in general. This allowed to re-center their daily and weekly experiences during this one-hour weekly meetings instead of researching what science practice(s) they took up during their designs. This is what led to the longitudinal, multifaced and multilayered approach towards a methodological framing of critical ethnographic multimodal case studies.

In our weekly conversations, the youth and I, analyzed, questioned and confronted our experiences and realities—in ways we have been racialized, gendered, classed and treated as People of Color in predominantly white spaces. Because of this continuous dialogic processing of our positionalities as youth and educators in this space (and education of others, such as community members) about the design work they did, the youth noticed there were a lot of meaningful experiences and opportunities for learning. It was not enough to write about those ideas as a descriptive study, but instead we decided to theorize a project where we would together (me and each youth) analyze our work together during P1 of the study and develop cases for P2.

Hence, in P2 of the study, the youth defined problems important to them and their communities and created solutions using varying perspectives important to engineering design, but also held their positionalities to this work as they understood the learning that went on and the movement of resources and disciplinary knowledge(s) needed in creating these designs in their multimodal artifacts. Their multimodal cases are an explanation of this learning from the perspective of the youth. However, many of the decisions of where to put these explanations on the case, or what multimodal artifacts to use were decided on together—this is why I call this a co-construction (or co-development).

At the end of the multimodal co-construction, it became clear to me that my relationship with the youth became more about our personal, experiential and supportive experiences which helped to see how these designs expanded to other areas of their life. Most importantly this led to the realization of how other people/teachers/community members can and should learn with/about the youth from their artifacts. The work is generative and iterative in unpacking the counternarratives of the culture of power towards expanding notions of learning for the youth across spaces, settings and time. These important critical understandings span multiple years and our relationship (me as a mentor to the youth in educational, personal, and emotional capacities) which still continues.

Data Analysis

Data analysis was guided by first looking at the problem spaces the youth were addressing with their designs, then how these problem spaces became or informed their counternarratives of the culture of power in science and then how these counternarratives led to expansive learning (Engeström & Sannino, 2010) across spaces and time. I used constant comparative analysis (Strauss & Corbin, 1990) to make sense of multi-year (2013-2016) ethnographic data and data reduction strategies to find themes across codes.

I began by open coding the online co-constructed cases of the youth's engineering work focusing on how they identified problems and designed solutions with their engineering designs through a lens of engineering practice(s) (NGSS Lead States, 2013). I then looked at how these problems were connected to broader issues of their communities (e.g. why did Faith create her what and for whom; what problems were the duct-tape tie addressing for AD; why did Christopher focus on an anti-bullying application).

Once these sections were open-coded, patterns emerged that tied the problems and perspectives of why the youth created their engineering designs to address broader social and educational problem spaces regarding learning. These social and educational problem spaces became a first approach to my sensemaking of what would constitute the counternarratives of the culture of power of science. Particularly, what were the goals of science the youth were engaging with their designs, but then how did the problem spaces that they were trying to address challenge or shift the ways we typically view science learning through these engineering design practice(s). What I found is that these counternarratives to the problem spaces the inventions were addressing and the solutions that they were creating with their designs were tied to other important learning experiences in school, at home in their communities that they decided to include in their multimodal cases.

These counternarratives were often multilayered and multidimensional. There were economic, social, political concerns, especially related to race, class and gendered dynamics of why their designs became counternarratives to the normative view of science. Merging these counternarratives with commitments towards understanding science knowledge(s) and practice(s), and the cultural/family/home needs they were addressing through their designs, allowed me to find important aspects of the cases that focused on movement of resources, ideas and ways they were accessed, activated, moved and re-created. My analysis was ongoing, and throughout data collection I transcribed interviews and video data that supported particular themes in design work.

In the third stage of coding, I now looked for movement of resources and expansive learning to make broader connections within cases. For example, what in the community did Faith take on for making her hat and how did that process inform her learning? In AD's case, I looked at what did it mean for AD to make her duct-tape design and then how did that inform other design work she created before and after the after-school club experience.

The fourth and final stage of coding involved me making connections between youth's designs and other social, community and educational problem spaces by now focusing on key qualities and patterns across cases by focusing on similarities and differences across them (Miles et al., 2014) related to how these merged into counternarratives to the culture of power in science.

The data were coded and subsequently member checked with youth throughout the entire process of data analysis since 2015. In the following section, I will describe the results section where I will first begin by describing each of the youth and their engineering designs and then I will describe three overarching claims regarding the youths' co-constructed multimodal cases of science and engineering learning.

Findings

In the next section, I will introduce AD, Faith and Christopher, their engineering design projects and analysis of their cases based on stages in my coding tree. In each of the stories below, I first introduce the youth and their engineering design ("invention"). I then present a series of section which detail the specific counternarratives authored by each youth. Within each of those sections I pay attention to how these counternarratives support more expansive learning outcomes. Then I will report on the two main findings of this study through cross case analysis using three conceptual categories.

The Youth Inventors & Designs

AD. In the opening vignette of this paper, I introduced AD, a 14-year-old Black Latina youth (Figure 3.1) who created a duct-tape thermometer tie for her father. Her primary goal was to “help people in their daily life, such as their health” (Introduction, Weebly page).

Figure 3.1: AD and her duct-tape hat.

Originally from the Bronx, New York, her father moved to Michigan when she was a young child. She stayed in New York with her mother, but as she grew up, her mother could not provide for her in the ways her father could in Michigan. AD’s father went to college but dropped out before graduating. However, with his education, he was able to land a “white collar job” (Interview 1) which provided comfortably for her and her siblings.

Unfortunately, after two years of living in Michigan, her father fell ill which forced him to become hospitalized for many weeks. Since he didn’t call his employer to discuss his health condition, AD’s dad was fired from his job. Subsequently, her father has not had the same opportunities to gain the same type of employment. Great Lakes City at the time was also experiencing an economic downturn due to the aftermath of the 2008 recession. Many industrial an auto manufacturing jobs were leaving the state and being outsourced internationally. These economic downturns were also creating economic disparities where lower income individuals were shifting to similar parts of the city. This created increased police presence and targeting of the Black community in the area where she lived. AD discussed feeling unsafe in her new neighborhood and affected her family greatly.

AD shared how this economic experience after her father lost his job has caused a domino effect in her life. Particularly, this experience has limited the time she sees her siblings because of transportation issues. She also cannot stay after school many days for band and other activities because of limited transportation availability. Her father works at various times throughout the day/night and his schedule does not permit her time to do extracurricular activities other youth could because she lacks reliable transportation. Eventually, this also strained her participation in after school at the Community Center as well. At her young age, AD is very aware of her economic situation, the consequences both racially and educationally this situation has had on her, and what obstacles she needs to overcome and the needs of her family to be economically and educationally successful.

When we began thinking of what problems to solve in the green energy club, AD discussed this about problems in the community:

> Safety issues were an important component of our design year….60 people in our [Great Lakes City] community came together to discuss important safety issues. Although most of the responses were around safety issues walking to school, or car safety... one of the answers that stuck out to me was EBOLA. At the time, there was a large scare of EBOLA coming to the United States from Africa…. [This triggered] memories of my dad getting sick from the illness he was diagnosed with when I was a young child. I really wanted to

> do something about it, but in a way that was cool, stylish and helps people be and stay healthy. (My Invention, Weebly page).

The survey AD described discussed in this example is one that the youth in the beginning of the design year gave out to community members at the Community Center and the Great Lakes City community. Although many members described issues in the community related to safety such as walking to and from school, car safety (such as child restraint seats), one person responded that they feared being infected with the Ebola virus. At the time, Ebola was an emerging potential threat in the United States.

Passengers were being scanned at airports using temperature sensors upon entry to the country and it caused a global health crisis as increased deaths were being attributed to this virus. Respondents in the Great Lakes City community triggered in AD experiences with her father's illness. AD wanted to prevent other people from suffering the physical and economic effects of this virus in the ways she and her father did. Ebola's onset was similar to the respiratory infection her father had, where the symptoms could be felt days even weeks after infection. Both of these problem spaces combined prompted her to design a duct-tape thermometer tie. The tie was designed to look like a regular tie using different colored designs so that it gave people options in wearing stylish ties to work. It also included a heat sensor that would change colors depending on the range of temperature of the person wearing it (Figure 3.2; Figure 3.3). In AD's view, color is significantly important. She discussed: "Duct-tape is in different colors and duct-tape is colorful. It's not black & white because duct-tape is not boring. They are the colors of ROYGBIV [red, orange, yellow, green, blue, indigo and violent] which are the same as the rainbow" (Introduction, Weebly page). She wanted her design to solve a problem, but not be boring in its use.

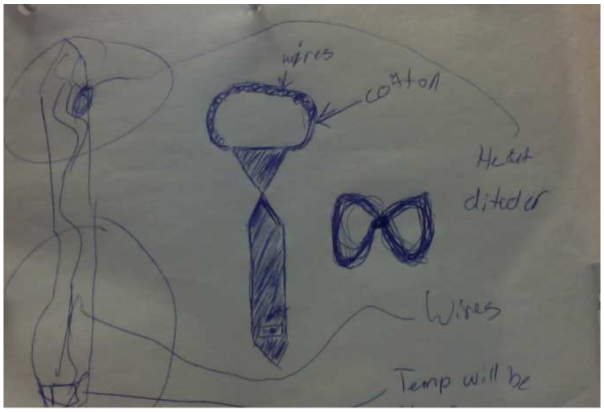

Figure 3.2: AD's thermometer tie SketchUp.

Figure 3.3: Technical specs of Duct-tape Tie design.

By connecting these two problem spaces: her father's illness and the onset of Ebola, and thinking about a colorful design, AD used duct-tape and engineering to design her tie. AD describes her duct-tape tie as "something that started small and the tie is pretty big in what it's' trying to solve" (What is Evolving? Page).

"Evolving is real": AD's counternarrative of the culture of power of science through evolution.

> "Evolving is interesting. Something so small can become something so big. Duct tape is the small and the tie is pretty big in what it's trying to solve. When my duct tape was able to do big things, that took a meaning of evolution for me. Evolution for me is something

> that was once small and unknown that makes itself from something else. Like according to science, we all evolved from monkeys or apes, something like that and became these super genius type people and created cities, and electricity and all this type of stuff, so we evolved. We grew. I learned about natural selection in my biology class, but I am more interested in Lucy which I learned in my World History class. I like how I am learning about science in World History with the case of Lucy. Anything can evolve, like the iPhone evolved 7 times already, and I am not too sure how, but if there is a will there's a way when something so small can become something so big." AD discussing her evolution as a student (My Evolution, Weebly page).

In her work, AD discusses the multidimensional and multifaceted ways people, places and things evolve. She not only described this through the evolution of her use of duct-taping, and as a learner, but most importantly as an inventor. Being able to connect the idea of evolution through the many ways she has changed over her lifetime, and view these as a type of historical narrative of who she is and who she has become, allowed her to be critical of her educational experiences. She connects this not only to her own evolution, but also to the tools she uses, such as duct-tape, which interests and designs themselves change depending on who uses them and for what purposes. The focus on Lucy is interesting as well. This multifaceted historization of how we can learn from Lucy allows us to see how epistemically different subjects (e.g. biology and history) focuses on Lucy's experiences differently. Finally, she notices that this type of evolving is also connected to things people use every day, such as iPhones, whose use changes depending on who is using it. AD reminds us: "anything can evolve" so why can't youth be viewed as evolving?

Lucy (the hominid) was such an important figure in connecting these ideas together for AD. AD described in her case how she learned in school that Lucy was the first "human" that was discovered who started "as a regular monkey and then decided to walk upright" (My Evolution, Page). She discussed that this happened because of "natural selection" through Lucy using her experiences as a hunter gatherer and passing this knowledge onto her future generations. These experiences in learning to gather food, and communicate with other animals, allowed Lucy to become smarter and support those Lucy('s) coming after her.

AD described how learning about Lucy resonated with her own experiences. First because Lucy was seen as evolving and that she was celebrated for sharing her knowledge(s) of experiences with her community, and that this collectively supported the evolution of her species. "If Lucy didn't learn all of that, then would I be here? No!" (Interview 5).

In the same idea, AD questioned why youth like her were not seen as evolving so that they could take what they learn to other places, like using new knowledge(s) to improve situations for future generations to survive and thrive learning from her experiences. AD's learning about Lucy in regard to her own life connected to two ideas. The first is how one as a person adapts to experiences and circumstances for survival for future generations. The second idea was related to what exactly is important to learn about Lucy, a figure that is millions of years old. AD discussed, if learning about Lucy is important, then why is it that we can't relate this learning to modern people, places and things which also have their own evolutionary history of survival (Field Notes).

In one of our discussions, we co-defined the meaning of evolution together: "By looking at oneself as evolving, one is understanding how one's making can help shape bigger and more important things--both in their meaning to the inventor and the use in the community--depending

on who it is for and what purposes those materials meet to support those bigger solutions*"*
(Interview 7). Here, upon exploring the e-portfolios and creating her online case, she was now beginning to connect evolution to herself as an inventor and why she created her tie and for whom.

In terms of her own evolution, AD in her case, discusses that her evolution began when she noticed how her economic situation shaped the choices she made in buying materials to make her inventions. Her duct-tape use began as a way to save money in buying more expensive toys/materials, but the duct-tape evolved with her to make things that were important and powerful for her community. These included: rugs from yarn, re-designs shirts and pants, designs costumes and mixes cosmetics and hair/body lotions from recycled natural materials. At the time she began her work in the green energy club, duct-tape was in style between youth her age. Having designed a duct-tape wallet, a duct-tape charger (by decorating simple chargers with duct-tape) and a reversible duct-tape hat for other youth at the club (Figure 3.1), oftentimes for free, she was already recognized in the club as being a duct-tape maker. Because of this recognition, when she entered the after-school club, she pushed to be recognized as a duct-tape maker and to bring her knowledge(s) and practice(s) making duct tape into the after-school space.

However, this push by her peers to duct-tape and wanting to be recognized as a duct-tape maker, created feelings of stress for her. She believed people did not know why she used duct-tape and how making makes her feel as a youth, learner and creator. In order to challenge this, she resorted to writing poetry that details her making experiences. One such poem, she called " how something so small can become something so big" (My Invention, Weebly page) because "through something that was once small and unknown that makes itself from something else"

(About me, Weebly page). This was also the name of her multimodal case. Her goal with her case in discussing her duct-tape design, her challenges to/what is important to learn about Lucy, her making and her poetry-writing was to recognize the evolutionary aspects of one's becoming and what supports (duct-tape, community, dad, friends at school) help one person become who they are at that particular time in their life.

Counternarrative of the culture of power of science in who can be an engineer. The experiences in the after-school club that AD had challenged a lot of her own views of who can do engineering and why. Because the work in the club emphasized engineering as "making," AD with her expertise in duct-taping already legitimized herself as an engineer. However, was she engineered the duct-tape tie she wanted and for the purposes that she wanted, the process of putting the pieces of her invention together challenged her views of who can be an engineer and what does it mean to do engineering. Particularly, this was evident in two points during her design process. The first was during AD's construction when coding the temperature sensor on the tie became an issue. The second pertained to how she used her learning from the duct-tape tie and the learning from her making experience to create solutions to broader community problems in Great Lakes City.

Counternarrative of engineering the duct-tape tie. Through various design iterations, AD figured that in order to create the colored temperature sensor she was looking for, she needed to use an Arduino coded Lilypad (Figure 3.4). The Arduino Lilypad used a special coding program on the computer and needed the person to understand the coding language the Lilypad called for. With using this Lilypad, AD's goal was to mimic the news doppler radars during the weather segments on the news. She discusses: "when watching the weather channel, I see that different places in the country have different colors (from purple to blue) based on how hot or how cold they are based on the temperature. For my duct tape thermometer tie, I wanted to do something similar, where the color of the sensor, would tell me the…temperature of the person [wearing it]" (My Invention, Weebly page).

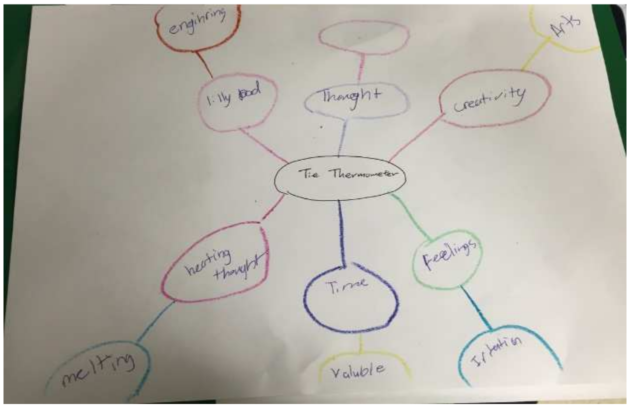

Figure 3.4: AD's tie thermometer and connections to other experiences.

In the following transcript, AD discusses this experience trying to code this sensor in her duct-tape tie.

Christina: So, after the word lily pad you have the word engineering.

AD: Yup

Christina: Can you tell us what you mean by that?

AD: Pedro [engineering undergraduate mentor in green energy club]. That's pretty much what Pedro is, he is an engineer. And he pretty much does all the technical work and stuff like that and he helps me with that. If there was no Pedro, there would be no tie.

Christina: That's interesting, in your map you put tie, lily pad, engineer. Are you saying that the lily pad is a connection between your tie and you being an engineer?

AD: Yeah

Christina: Can you tell me how?

AD: Well the Lilypad is making me do all this coding and stuff and it's also making me have to connect wires and it's this thread wire that we have that I use. I never knew there was such a thing as thread wire. Or my bad electrical wire, whatever you want to call It. So, if it wasn't for that I don't think I would be an electrical engineer. There's a bunch of different forms of engineering (Mid-Artifact Interview, 2015).

In this transcript, AD began by describing that she was having trouble coding the Lilypad and that Pedro (her undergraduate engineering near peer mentor) was helping her to code. Her words of "if there was no Pedro, there would be no tie" legitimized Pedro as the expert on the Lilypad, However, she then discusses that "[the lilypad] is also making me have to connect wires and it's this thread wire…so if it wasn't for that I don't think I would be an engineer. There's a bunch of forms of engineering" (Mid-Artifact Interview, 2015).

In a later interview, AD discussed how in school, youth were not taught about how to use these computer programs and coding software even though society is becoming increasingly reliant on them. She noted "I don't know how to type… I don't know how to use any of that coding and I think I need it someday, but why don't we get it taught in school. All these kids in other places like [affluent city near Great Lakes City] have competitions on how to do coding stuff and I just don't know why we're not taught to do that stuff" (Interview 7).

These connections between coding and opportunities to code are significant. She noted her lack of knowing how to code the Lilypad as a significant barrier to engineering, but at the same time she legitimizes Pedro's expertise in coding as her bridge to engineering. However, she notes that engineering requires multiple expertise(s) that one can have in relation to an engineering design. Meaning that she understands the disciplinary need of science and engineering to work together and gain multiple perspectives in order to make her design, but she then notes that this inability to code is a barrier that youth in other more affluent districts have and even engage in competitions for. For her, Pedro is like a teacher, and her teachers don't provide all the bridges to opportunity needed to be competitive. AD’s ability to unpack the opportunity gap that not knowing how to code and even type on the computer provides is a great challenge to what it means to engineer in the culture of power of science, but her own legitimization of her expertise in electrical engineering is critical.

Similarly, Figure 3.4 shows different connections between her tie thermometer to different areas of her life. For example, she sees that the tie thermometer is connected to creativity, thought, feelings and time to create. She also included technical aspects of the tie like learning that the temperature sensor can make the duct-tape melt (which she learned could be dangerous for the person wearing the tie) and the experience of using duct-tape caused feelings of irritation for her because people ask her to: “make, make, make, but never ask why and what I feel” (My Invention, Weebly page). These feelings are not only connected to the duct-tape itself, but also the process of creating the engineering design project from start to finish (Field Notes).

After not being able to complete coding the tie, AD found online that Littlebits, or pre-coded gadgets, could be used in lieu of the Lilypad. Littlebits function like a Lilypad, but without requiring the person using them to code its functions because they come pre-coded for its intended use. For example, some are pre-coded to function as fans, and others are pre-coded to function as buttons that light up. The tie ended up using a room temperature Littlebits sensor that when connected to a battery read the temperature in the room and read it on a small screen. Although it was not what she wanted, she ended up incorporating this design into her tie.

Counternarratives of struggles in making to learning science. AD’s experience with the temperature sensor prompted her to seek a better understanding of how people learn to read scientific content (like coding) which otherwise no one taught her to do. As AD started noticing the connections between who can be an engineer, the problem spaces around engineering and the struggles to create using engineering practice(s) (and knowledge(s) of specific types of content and practice(s) to make), she started connecting these to broader views of her struggle to who *can make and gain from the struggle* in her community. She discusses:

> People go on shows like Oprah and say the basics like I love giving back to the community and I remember where I came from…and the struggle, but they don't really know what the struggle is. To me, the struggle is life and what you go through… and the struggles teaches you to be a better person and who you are at the end… eventually my experiences showed me the struggle (Helping People, Page).

In her case, AD discussed who has access to knowing what engineering is (like her positioning herself as an electrical engineer) creating/making engineering because of the struggle (like her duct-tape hat), and eventually who can capitalize on engineering (for free/ for the community). One of her goals was to create a duct-taping fashion company (Duct Tape Evolution, Weebly Page) for youth who could not buy fashion design products, and she did this by re-purposing and recycling materials from other sources (Interview 5).

Another way that AD discussed the struggle was related to making in the Black community. In her case, she described how she and others in her community fare worse from those using capitalism to profit from "the struggle" even though there are good intentions. In one instance during our case development, we discussed the company *Shea Moisture*[6], which according to AD, makes oil, cream and hair product marketed towards the Black community.

AD described having to sacrifice economically in order to buy these products for herself. She discussed "Companies like *Shea [Butter]*...they are so expensive, and I just can't. I want to

[6] Shea Moisture is a small minority owned business that has been producing Shea Butter products for nearly 100 years. They are equity-minded in their approach to supporting national scholarship opportunities, local investment and giving back to communities where they outsource their products.

make my own products and less expensive" (Interview 5). In this same interview, AD added to her case how she has been working to create coconut oil-based products and her own creams and lotions as a way to challenge the corporate/economic hegemony that exist in Communities of Color (see Figure 3.5). She stated:

> So right now, one of my absolutely favorite things to do with my time is making soaps, deodorants, make up, hair sprays/conditioners/leave-in creams, conditioners, body oil, with coconut oil. I keep asking myself why people buy so many things that just have a fancy name and a nice plastic cover if in reality, especially with those nice messages …You know they are not going to use them. I've seen my people throw money in the garbage with all the stuff they buy. Coconut oil is amazing because it's all natural, and it comes from trees which are the same ones that give us oxygen. So, if we breathe in air from these coconut trees, why can't we use the same trees to moisturize our body. (My Evolution, Weebly page).

Here, AD is clearly connecting ideas between her experiences making, and in some cases using scientific literacy in knowing the types of chemicals that these products use in relation to natural products she could re-purpose to make it less expensive for her community to buy. Although companies like *Shea Moisture* have community members needs in mind in designing and marketing their products, for AD there is a clear gap between the affordability of these products for her community and the profits of corporate/capitalistic notions targeting Communities of Color. Specifically, AD wanted to challenge the power dynamics related to affordability of products in the Black community and how by knowing about science and the ways products are made, she can create coconut-oil based products that can be equally beneficial, but also economically sustainable. In order to educate her community on issues of how affordability of products continue to create divides within her community, she has connected her learning about lotions, soaps and creams by making videos on Facebook Live and YouTube teaching people about re-purposing materials for making hair, face and body products (Field Notes, Facebook Live video 2015).

Figure 3.5: Coconut-based oil products made by AD.

Ultimately, these economic struggles in her community and connecting them to broader science knowledge(s) and practice(s) that are taught in schools led her to realizing that purchasing these materials that take advantage of minoritized Communities of Color are not a coincidence. She noticed that in her K-12 science experiences she has not been taught to be critical of her learning, further creating divides between her and science knowledge(s) and practice(s) that may be helpful for her to make economic, social or political decisions She then continued to counter-narrate the ways she wished to see a critical and engaging view of science learning in her school.

For example, AD discusses how in science class: “I am assigned more book work...I can tell them to give me some more free will [in science class] to do what I want to do. I would want to do more projects, maybe like a box project and/or make posters, creative things, stuff like that...I want to make things for my people not learn meaningless things” (My Invention, Weebly page). AD also goes on to describe that if she could, she would show her teacher her design because "my [8th grade] teacher…she likes when I make ties, but I want to show her that I can make them…better and more meaningful" (My Invention, Weebly page).

During the time of the case development, AD was transitioning from middle school to high school. Through this experience, she focused on how she views science learning as further minoritizing her in her learning:

> Homework [in high school] is so difficult. This is crazy… we have five homework pages a week and by the time we are done doing that homework they are not due until the week after next and by that week, we are not working on the same homework from last week….this is my biology notebook, it's just more and more and more and just like that [while sifting through the pages and showing them on the screen]...I feel like I have the life of a robot and was programmed to have this life" (Teachers learning from youth video, AD's website).

These discussions clearly state how she sees the lack of relevance of her science experiences in school to the ways she wants to learn (e.g. making posters, creative things). In further discussions AD discusses how she has begun to notice how these experiences seem to be placing "kids like me" in these positions where they become robots and are programmed to have a life of doing menial worksheets and following directions instead of doing science experiments and "box project and/or make posters, creative things, stuff like that." The ways that these ideas together are connected, multilayered and multifaceted, is evident in the problem spaces for why she decided to create her duct-tape thermometer tie and for what purposes. Table 3.2 discusses AD's counternarratives, expansive learning and movement of ideas/resources important in her case.

Table 3.2:
AD's Counternarratives, Expansive Learning and Movement of Resources in her Case

Youth design	Community Problem Design was Solving	Experience in After School Program Related to K-12 Experience	Counternarratives of Culture of Power in Science based on Cultural, Home & Schooling Experiences	Expansive Learning Outcomes	Ideas/Resources Moved across Spaces
Duct-tape thermometer tie	Dad lost his good paying, "white collar" job due to respiratory illness. Economic challenges in the community limited opportunities AD connected Ebola scare to her economic experiences with father's illness and did not want others to suffer same consequences Safety in her community tied to economic minoritization after 2008 recession.	AD is a duct-tape expert in school and after-school program Duct-tape was affordable and economical for people in her community Considered herself an engineer through duct-taping and using tools of design (e.g. electrical tape/wires) and wanted to share expertise with others in school and community	Resource availability in school settings (e.g. duct-tape) Settled science knowledge(s) and practice(s) limited opportunities to view youth as evolving by expanding on past and present learning (e.g. Lucy, tech connections) Needed to express tensions in making and views community members had of her (e.g. connecting poetry to making) Viewed science as racist (e.g. Shea Butter although wanted to sell products geared towards Black community can also be an economic burden on communities) Questioned overreliance on textbooks as a form of learning. Science should be personal, hands-on	Expanded engineering knowledge(s) to create inventions community would use (recycled home products, rugs, duct-tape decorations, re-purposed clothing from winter to summer). Made lipsticks, make-up, creams, hair products and learned the value or sharing those with community members through YouTube and Facebook live. Legitimized her experiences through poetry and wants to center her writing to merge her feelings in community with her learning (connections to Lucy's experiences).	Materials (duct-tape, coconut oil products, recyclable materials) People (her father, community members scientific literacy, Lucy, teachers learning from youth) Places (Community Center, Ebola affected countries, home in creating case and in creating designs, school) Evolution (evolution in school, in life, in community, in ontological becoming)

Faith. Faith is a 14-year-old Black female "engineer and psychologist" interested in using engineering to help people feel better about themselves physically and emotionally (seen in Figure 3.6). During the time she co-constructed her multimodal case, she pondered very deeply about her participation in the after-school club and ways she could have improved her design to better meet the needs of her community members. Faith's most important goal was to unpack the multifaced and multidimensional problem spaces her design addressed and how that learning carried through her goal of becoming an engineer and psychologist. She analyzed these important connections in her multimodal case study.

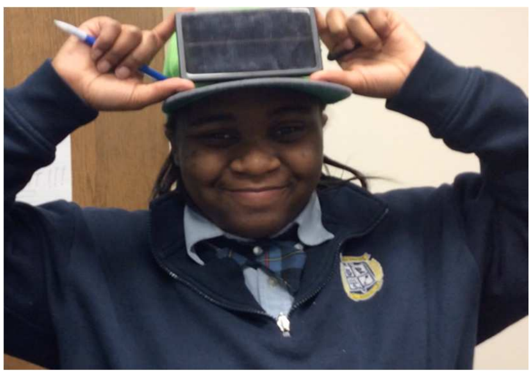

Figure 3.6: Faith and her initial FANcy hat prototype.

Her goal with the solar-panel FANcy hat was to "to take care of her community in ways traditional school learning did not allow her or support her in doing" (Interview 1). She stated that "[in the after school green energy club] we learned about green energy and using technology to help people; they told us to think about an invention that can help other people in our community. If you notice, the name of my website is called imagination creator. I really think I create things with my imagination and if we don't use our imagination then how can we make up new ideas?" (Interview 3).

Faith's imagination was critical to connecting various cultural and learning experiences related to her FANcy hat design. This is especially because she thought of broader community problems and connections of her hat during and after the multimodal case study development, which shows her important meaningful and expansive learning experiences as a result of making her hat.

Before working on her fan hat, the after school green energy club asked youth to ponder about *general* community problems they wished to solve that used green energy technologies (e.g. solar panels, hand cranks). Important here is to discuss that Faith's participation in the after-school program happened the year before AD's and Christopher's, so the problem spaces that were investigated were different. For AD and Christopher, the focus was on safety issues in the community and they built designs focused on safe spaces/commutes.

Before beginning her design, Faith discussed in her case that the most critical learning experience during K-12 at the time was when she took a field trip with the green energy club in 2012 to the only solar panel house in Michigan. This experience taught her that by using solar panels, energy can be harnessed to power up entire homes and electronic devices while reducing people's electric bills (Field Notes).

Faith discussed that after this experience, she went home and discussed with her family what she learned. In her case, she wrote: "Like in my family, my brothers like to use their Wii a lot and the controller runs out of batteries [all the time]. Because I know how the environment can be affected by how we use electricity and things that contribute to global warming, I told my father to buy rechargeable batteries for the Wii Controller" (My Invention, Weebly page). For Faith, it was critically important to design an "invention" that used a solar panel, but that the design helped "stop global warming in the same ways the solar panel house did" for her community members in Michigan (Field Notes).

Important also to her case is how Faith challenged the normative views of science during her design process. She felt that "experts" were critical, but that the design process they called for were not true to the needs of her community. Her design work was full of important and critical tensions that she navigated through in order to better achieve the design. These steps were later discussed in her multi-modal case and what allowed her to shift her design towards community-centered practice(s). In the next section, I will describe various counternarratives as seen throughout her engineering design work and how these contributed to expansive outcomes in her FANcy hat design.

Counternarratives with connecting science to multiple problems in community. One important counternarrative to Faith's science learning was related to how she purposefully bridged multiple problem spaces in Great Lakes City and beyond to the purposes of her FANcy hat design. Not only did she center these problem spaces, but she challenged the normative views of how to engage in engineering design work by centering the community problems she learned throughout the design process.

Originally, Faith wanted her hat to "be funny while keeping cool" and that people were "sure of themselves in ways that they don't have to be hot and sweaty all the time" (My Invention, Weebly page). For Faith and her FANcy Hat, cool had many meanings. The first meaning was related to helping her Grandmother stay "cool" while attending church service in an un-airconditioned church in Florida. She felt compelled by seeing her Grandmother take off her fancy church hat because she was "sweaty all the time" (Interview 1). The hat was also meant to protect her friends and family from being "hot and sweaty" in public (which she feels could contribute to problems with self-esteem) and finally how the hat could even prevent "skin blisters" from excessive exposure to sunlight that may lead to "facial skin cancer" (Interview 1).

Grandmothers at church. Before starting the design, Faith noticed that in her Great Lakes City church there were opportunities to harness the energy of the sun in ways that connected to the solar panel house experience. She stated: "At church we have lights that function like solar panel lights on top of the spaces where the sunlight can come into the church. If we can use the LED lights in the church, maybe if we use a solar paneled hat, it will allow us to reflect this important solar energy on the solar panel to use my fan." (About me, Weebly page). When she began her design in 7^{th} grade, she was concerned about her Grandmother's church experience. She did not want to constantly see her Grandmother, who attended an un-air-conditioned church in Florida, take off her fancy hat during the service. She felt that the "church hat is a cool way to showcase your personality during church and my Grandmother shouldn't have to take it off because she feels hot and sweaty all the time" (Interview 1).

In thinking about this problem space, she connected her Grandmother's experience in her Florida church to the ceiling in her Great Lakes City Baptist Church. The ceiling in this church had openings, which during the service let the sun in. There were days when the sun was very bright, and people could not see much in front of them. This was also important for the use of her hat. There were other days, when it was so hot, Grandmothers had to take off their church hats. In addition, she noticed that the church was spending a lot of energy trying to cool off the church. She then thought about "making a solar-paneled hat with a fan in the middle" (Final Artifact Interview, Faith).

In multimodal case Faith co-created years later, she mentioned how church hats are an important staple of her Great Lakes City Black community. Grandmothers (Figure 3.7) wore their elaborately adorned hats to church as a cultural-historical symbol of resistance and uplift. Faith's view of Grandmother's wearing church hat to Sunday meant that they centered who they are in their community spaces. Conversations that arose around sharing beauty and elegance from their church hats was an important cultural-historical symbol for Faith, her family and community. In particular, Faith noted that:

> A lot of elderly women are stylish, and the hats are an important part of who they are, but at the same time it is difficult for them to keep cool during the church service. In Michigan during the summer time it gets very hot, but because there is limited to no air conditioning, we can't do anything about it. I always admire the Grandmothers and their hats. They should be able to keep their hats on the whole time, but sometimes I notice they take it off because it really does get extremely hot in church (About Me, Page).

Faith felt that during church time every week, the community comes together to discuss happenings that occurred in the outside world. One example of this is her showcasing her Church's Women's Day weekend as part of the Pearls of Wisdom program. Faith felt that the church space is the only safe space to share experiences, culture and food in her community. The harsh economic and social realities of feeling safe as a Black community member in Great Lakes City were being shadowed by headlines that unfairly targeted Black community members nationwide (e.g. shootings, killings, fear of persecution). Hence for her, the FANcy hat was not only for Grandmother's to use purposes of keeping cool during the summer time, but it was also a symbol of protection, safe spaces, resilience and uplift for members of her all of her Grandmothers who attend church communities. Her FANcy hat design centered these problem spaces as counternarratives to broader social and racial struggles of the Black community in Great Lakes City and used science to achieve it.

Figure 3.7: Grandmothers at Faith's Great Lakes City Church (picture taken from church Facebook page and put in her case).

Connecting FANcy hat to skin cancer. During her co-constructed case, she then connected the ways sun exposure in all ways and forms can "kill us," referring to how misinformation about skin cancer could be detrimental to the Black community in Great Lakes City. She noted: "Blacks have higher rates of death due to skin cancer than other groups, and that people think because we have more chemicals in our skin, we are more protected" (Interview 4). In one of her interviews she discussed "I am scared someone in my family will develop skin cancer and me too" (Interview 3). In the same interview, she discussed how the sun's energy can and should be used to keep people cool without exposing them to the dangers of the sun (Field Notes). Not only was Faith concerned about centering community knowledge(s) and practice(s) at church, but she was also very concerned about the misinformation related to health issues and global climate change that affected Communities of Color. Hence her FANcy hat also became an educational symbol for her community.

Counternarratives of what "engineering materials include my community." One of the most difficult decisions of Faith's work on the hat was choosing a hat that would reflect the needs of her community. She first thought about using a hat with a propeller on top. This idea came from her mother's local directing of the play, Smokey Joe's Café in the Great Lakes City theater. While joining her mother during rehearsals, Faith noted that props at the play used "funny hats," She wanted to take the propeller hat to the club to use it on her design. After noticing the difficulty of using a hat with a "propeller on top" because the "air would not go on the user's face" (Field Notes) she then decided to take her only "furry winter hat." She thought this hat would be perfect because the furry winter hat could include a fan, solar panel and a space for earphones to listen to music on the flaps. However, due to economic reasons, she decided not to work on her only winter hat (Field Notes).

Upon the suggestions of her after school mentors, Faith went on YouTube to look for ideas on how she would combine her initial thoughts on creating her solar-panel fan hat. Her findings indicated that she found a design that was "cut the middle of the hat right here [pointing to the brim of a hat] and started connecting the fan right here [facing the user]" (Final Artifact Interview). However, from the video she could not figure out what material the baseball hat was made from, and she could not quite tell if the hat's brim was flat or curved.

Once she settled on using a baseball hat, she decided to start working on finding the best hat for her design. She came across problems related to the brim and leveraging the use of the brim for the solar panel design. She thought that the flat brim would provide some stability to her design, allowing the fan to move without hurting the person wearing the hat. But she also saw that flat brims were used more in her community. Many Black youth in her Great Lakes City Church who played basketball only wore flat-brimmed hats.

She also thought about how Grandmothers at church children or grandchildren had who wore flat-brimmed hats in style based on their favorite basketball/baseball teams. The curved brim hats were representative of a more rural style which she felt did not represent the needs of her community. Eventually she did not want this misrepresentation to challenge the use and function of the hat. However, after testing a flat brimmed hat she thought more about the affordances and constraints of the curved brim. Her solution to the style problem was to use a *Michigan State* baseball hat (Figure 3.8). The MSU sports theme would have its own currency in her community allowing her to center her community in the choice of a hat that was best for the solar panel design. As Faith stated:

> Because when you use a snap pack it has a flat surface for the part that covers up you're like um the piece in front of your eyes. And it like, we needed a curved one so not like a flat deck, not even long enough. So, we decided to do like a baseball cap and because it had the right length to put the fan on and another part where the solar panel can be put on top and so yeah. Um and yeah, we decided to do a Michigan State hat (Final Artifact Interview).

Similarly, Faith was having issues on what size solar panel to use that would fit the hat and do its purpose in turning on the fan. In one of her transcripts, she stated:

> **Faith:** Well the hat, if it actually spins, like the solar panel has to be bigger so it can get enough sunlight to spin.
>
> **Christina:** So you figured out the solar panel didn't have enough [solar cells]?
>
> **Faith:** Yes, because the lamp had to be closer for it to work.
>
> **Christina:** So does it spin fast when the light is near?
>
> **Faith:** It'll spin fast.
>
> **Christina:** Have you tested it to see that it actually hits air into your face and that its' working?
>
> **Faith:** Yes.
>
> **Christina:** So what doesn't work about it, other than the solar panel?

Faith: If you are outside as it really does. It will just like, it will see light, but it won't spin because the solar panel is the small size.

Later, she worked on finding the power requirements of the solar panel and these were her calculations: "yeah, that's the voltage of how far away the solar panel. So, when it's 1 feet, its 3.68V, when its 2 feet, its 2.78V and 3 feet its' 1.5V…We had Angela and Elaina hold the two wires right here (pointing inside the fan where the rotor wires met the solar panel) and then we measured how many volts it had" (Final Artifact Video).

Figure 3.8: Faith's FANcy Hat design.

She tested two different types of solar panels, 5V and 10V. What she found was that the bigger solar panel worked better, but it did not look stylish on her curved-brim hat. These created tensions between the functionality and style in use of the hat. Eventually she went with a smaller solar panel, which needed more sunlight to power up and the curved-brim since it was easier to wear and didn't hurt the user wearing it.

Counternarratives to how engineering centers community. As stated earlier, one of Faith's main learning experiences during the hat design and in her multi-modal case was how her hat challenged what it means to engineer. Finding that her engineering design was in reality a community-centered designed challenged her views of what it means to do engineering and subsequently focused on her creating a page on her Weebly focused on only “doing engineering” (My Engineering Cycle Page). During the engineering year in P1, mentors in the after-school club focused their efforts on teaching engineering design from the perspective of NASA (National Aeronautical Space Administration) scientists. NASA is a United States Federal Government agency responsible for the civilian space program as well as aeronautic and aerospace research housed out of Washington, DC (NASA, 2017). Particularly, we, the mentors in the after-school space took from the NASA Engineering Design Process (NASA, 2017). Given that this cycle was the most aligned cycle to engineering work done by practitioners in engineering at the time, from an agency the youth in the club would recognize, we felt it was the most appropriate to use in the after-school program. When Faith began discussing ideas of her engineering design project noticed how the NASA cycle did not include ideas of community in iterative and generative ways. Rather, the NASA cycle in this case decontextualized community knowledge(s) and practice(s) not allowing Faith to find her community problems within the cycle. In addition, when Faith began to challenge the NASA cycle through the continuous iterations of her work, it was evident that for Faith, that NASA seemed to be intentionally erasing the knowledge(s) and practice(s) of why and how problems of practice in creating designs were important (especially for those wanting to use the NASA cycle for their own engineering work). When Faith went back to her invention and this process came in tension with what she was seeing, she began to question why community, race and gendered dynamics important in her engineering design such as the reasons for making the hat, how community can add perspectives to change parts of the hat or designs within the hat, even who can use the hat (flat vs. curved brim) were completely missing from the NASA cycle altogether. In our work together, Faith and I saw that the epistemological and methodological ways of being in design that were completely erased if one used that cycle. Eventually, this work not only critiqued, but gave way to a new view all together of how science is colonialist in its intentional erase of knowledge(s) and practice(s) of communities and through her own design of her engineering cycle, she was able to challenge these colonialist notions—creating a new epistemological and methodological design process that does incorporate knowledge and practice in/within communities.

In doing her design, Faith argued that the problems and solutions that she designed were driven by constraints and the people and communities who would benefit from her invention. In designing her solution, she looked at three specific solutions 1) finding the right hat that fit the needs of multiple community members 2) finding the right solar panel size for the voltage requirements of the fan and 3) finding a hat that represents her community. She figured this out by looking at specific resources and ways she moved these resources across spaces in her design work to make sure these three solutions were successful.

Finally, Faith described making engineering design choices based on her perception of being an imagination creator. She argues that her design, by keeping community concerns at the center, identified the best approaches to solve community problems throughout the engineering design cycle of the FANcy hat. By centering community throughout the process, she authored a new way of re-purposing tools and experiences of engineering which she calls Psychoengineering. Psychoengineering came from her sharing her experiences in making the hat for her community through challenges in the design process (Field Notes). In the same ways that she learned to merge community design with engineering practice(s), she is now attempting to merge the tools/experiences of engineering to form new therapeutic methods for mental and physical health in Communities of Color. These experiences came from conversations with her mother who was the only Black public health professional in her practice and was targeted unfairly by her white co-workers. Psychoengineering was co-created with her mother as a way to help her feel better about herself at work (Field Notes). Table 3.3. shows Faith's counternarratives, expansive learning and movement of resources in her case.

Table 3.3:
Faith's Counternarratives, Expansive Learning, and Movement of Resources in her Case

Youth design	Community Problem Design was Solving	Experience in After School Program Related to K-12 Experience	Counternarratives of Culture of Power in Science based on Cultural, Home & Schooling Experiences	Expansive Learning Outcomes	Resources Moved
Faith designed a solar-panel fan hat	Her Grandmother who attended an un-conditioned church in Florida Grandmothers at her Great Lakes City church who wore elaborate church hats Friends at track were developing skin blisters during practice(s) and wanted to solve problem for them	Entered club as a way to learn about green energy and became conscious about solar and green energy technologies at school and home Critical of school science by centering her experiences making for community and challenging narrative discourse of engineering and scientists (e.g. NASA cycle)	Created her own community-centered cycle because all designs are different because community problems and design practice(s) are different Black community are not taught the dangers of cancer-causing sun light rays (connections to scientific literacy) Engineering design experience taught her tools to overcome tensions between struggles in community and in everyday practice(s) Challenged views of community spaces such as churches as powerful places where the Black community feels safe.	Faith saw herself as an imagination creator because her design used community problems through imagination View of Psychoengineering centered tools of making in engineering as a therapeutic tool for Communities of Color.	Family (mother, brothers, Grandmother in Florida) Community (Grandmothers at church, community through engineering design cycle, centering church as a stable of her community, friends in track, friends at school by centering aesthetics they value) Care (care for functionality of hat, care for community to prevent cancer; care for Grandmothers at church to wear symbols important to them)

Christopher. Christopher, a 13-year old 7th grade Black student from Great Lakes City, MI is "an avid technologist and active science learner" who enjoys learning how to create smartphone and computer applications with his adult Big Brother[7] mentor on the weekends (About me, Weebly page). In the green energy club, Christopher created the Speak Up Step Up (hereinafter referred to as SUSU) smartphone application (Figure 3.9). His goal with the project was to stop bullying in his Great Lakes City community.

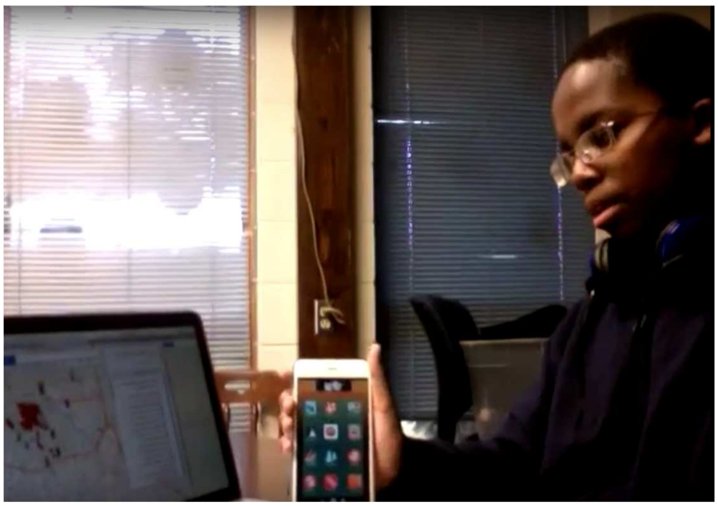

Figure 3.9: Christopher and his SUSU app.

While designing SUSU, he described himself as an "inventor and destroyer." As an *inventor,* he is passionate about using interactive technologies to make the world a better place for himself and his friends. As a *destroyer*, he wants to destroy the act of bullying—including the frustrations and emotions that are harbored by its effects on his local community. He believes using technology can be used as an educative tool to become better members of our communities:

[7] Christopher is part of the Big Brother Big Sisters program. Their goal is providing children facing adversity with strong and enduring, professionally supported one-on-one relationships that change their lives and help them achieve success. Christopher's Big Brother mentor visits him on Saturdays and is a technology employee at Midwestern Research University

helping is loving someone else in the heart because helping is very important in making the world a better place to live in community. My app should encourage you to help others not only by supporting our community in preventing bullying but also in taking the time to help others who are being bullied by caring for them and seeking help when needed. (Introduction, Weebly page).

SUSU was created using Global Positioning System (GPS) and Geographic Information System (GIS) mapping technologies in combination with community crowdsourcing to pinpoint common bullying areas in the Great Lakes City area (Figure 3.10). His case, although analyzed his engineering design work, was more geared towards creating a public campaign to stop bullying between youth locally in Great Lakes City.

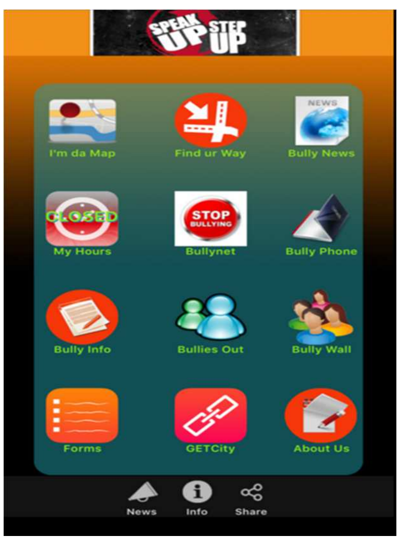

Figure 3.10: Christopher SUSU's app.

Counternarrative of speaking out against bullying in science class. For many years Christopher, has been a victim of bullying both in his school and at the Community Center of Great Lakes City. In 5th grade, he experienced a bullying incident in his science class which occurred online, but his bully decided to bring his attack to school and did so during recess. Christopher, instead of taking a physical reaction towards his bully, decided to tell his teacher as he believed this would be the safest route. Rather than quietly handling the situation, the teacher decided to publicly discuss the matter and punish the student openly about having bullied Christopher on that occasion. This created a situation of retaliation, where Christopher was further bullied in subsequent occasions by the same perpetrator in his school and then, after school space.

Christopher discussed that by discussing the situation with his teacher, he did not solve the problem because 1) the aggressor was now recognized for being a bully by his teachers and classmates giving him more power over others, essentially instilling fear in his classmates and 2) since the aggressor knew who had denounced him, he continued to bully Christopher and his classmates in response to being exposed publicly on the situation. Because of these experiences, Christopher discussed that he needed to take an "action instead of a reaction"(Interview 1) to bullying because by taking an action, something is being done with and for others, however when taking a reaction, the situation becomes individualized, a confrontation and possibly fall out of our hands creating a larger issue that can lead to graver consequences (Field Notes).

Due to being victimized and minoritized by continual bullying, Christopher and his peers experience fear in their local community. Christopher has even reported that some youth have taken their own lives as a result of bullying. One of his after-school program peers recently took their own life due to bullying in their local high school. These experiences have taken a toll on Christopher (and his friends). He hopes his anti-bully application allows for a renewed sense of purpose for Great Lakes City by acknowledging that bullying is a problem in his community and that it takes place, while also working together to eradicate it.

Counternarratives of building SUSU and knowledge of Great Lakes City with community. One of the greatest parts of Christopher's online case was his unpacking of the ways he built his SUSU app with his community. In his multimodal case, Christopher discusses:

> This app was made by [Christopher] and friends in [the after school green energy program]. The app began as an idea and then that idea became a reality. [Christopher] is an inventor who came from the club. My dream is to become a successful person and run my own business…To me this app means that I have done something good to help the world be a better place." (The Behind the Scenes Look, Weebly page).

Christopher in his design focused on giving credit of his design to his friends and community members. He views this through co-creating knowledge(s) of community through a series of what he calls "pancakes". Pancakes, according to Christopher, are a way to view how the data gathered could be layered in his smart phone app. Christopher created four layers of pancakes in his app. He states the pancake layers as follows:

> The first layer is questions on the online survey monkey that we gave to people in the Community Center so that they can tell us information about themselves and where they are most commonly bullied. The second layer of pancakes was the GIS map on Google Maps that helped us pinpoint locations, the third layer of data was using online crime websites like crimemapping.com and the fourth layer of pancakes is the real-time data of people experiencing bullying right here, right now" (Identifying Problems, Weebly page).

Taken together, these layers offer a rich multidimensional counternarrative for how youth like Christopher experience and respond to bullying in Great Lakes City. At the same time, together, these layers built an educational foundation for improving knowledge(s) about their community from the perspectives of its members. When first thinking about building the app, Christopher was thinking about how community members discussed problems of bullying in Great Lakes City. His first survey asked questions regarding demographic and age-specific information, if community members have been bullied previously and locations, and what type of smartphones community members used so that the application met the varying needs of smartphone users.

With this first survey, he found that when community members (n=15) were asked what "intersections" or exact locations where they have been bullied, the survey participants could not answer the question with accuracy. For Christopher, this was an important finding because he assumed that his community knew locations within the city, specifically the intersections that they walked on when going from home to school, or to the after-school club—even those near their homes. In his survey, many community members referred to specific places based on their proximity to commercial or developed areas in the locality. These included proximity to small businesses (e.g., local Fish Fry), or near large corporate stores (e.g. Meijer, Walmart, large megastores), schools, or places of worship. This meant they had limited geographical knowledge(s) of the names (but had specialized knowledge(s) of intersections based on proximity to home/school/business locations) given to streets in their community.

Building from community knowledge(s) provided an important counternarrative of naming community spaces for Christopher's case. He encountered during his data collection that community members began to discuss narratives of violence, racial segregation and oppression near their homes/businesses in the community based on the proximity to locations frequented by his community members. To community members, Great Lakes City is colloquially divided into four parts: north side, south side, west side and east side. These racial and class narratives told by members during data collection for his app were often accompanied by discussions of opportunities for work, opportunities for higher education, crime and imposition of how/which types of benefits or services these members had access to. Community members also began to connect broader discussion of crime narratives to issues of bullying. For example, one young community member described that near her home in the "south side" crime was more normal and that she thought "bullying would not be a surprise in that area." So, for that community member, and as Christopher later discussed during our member checking, "if there was crime, then there had to be bullying there too."

After experiencing a trend in the community survey feedback, either by knowing or identifying specific geographic areas in lieu of community intersections, it became imperative for Christopher to find a way to connect this knowledge(s) to his problem space of bullying in designing his app. For one of his community responses, Christopher approached a community elder known as Granny, (as she was affectionately called by everyone, me included) to complete his survey. Granny did not know the intersections where the bullying she witnessed occurred. Because she had a difficult time remembering, Granny asked Christopher to show her a map "like those you see on the GPS." Christopher opened a Google Map page for Granny to tell him where she saw the bullying happening. Instead, he noted that on the Google Map, it was easy to "click" or "pinpoint" the location on the map. In testing this new understanding with Granny, he clicked on the map and noticed that the map dropped a pin on the location, allowing you to save the name and description of that location. He then noticed that this type of method could be used to gather ethnographic data with names and descriptions as an effective way to "see bullying" on the community map. He then decided to use this to co-construct knowledge(s) about bullying in the community through Google maps (Figure 3.11).

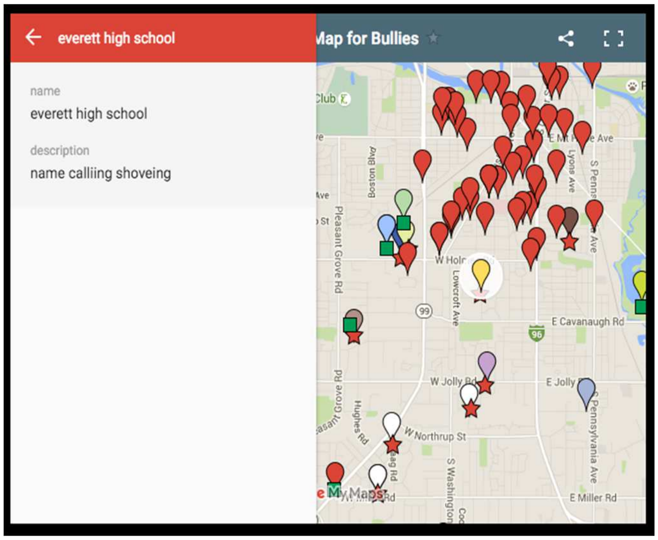

Figure 3.11: Mapping through Google Pins

As Christopher continued to use “pinning” on Google Maps as a way to gather ethnographic data, he started seeing that different colors can be used on the Google pins to signify different types of attacks.

This new data collection method allowed Christopher to focus on the geographical zones, but also on the experiences of those locations. It provided information whether or not multiple people have been bullied in the same places, or if people were being bullied in multiple locations, and if those experiences have been similar, allowing to make claims on frequency, time, and place of bullying. Furthermore, the pinning allowed for community members to expand their knowledge(s) of bullying to ultimately include crimes that occurred in the city in days prior based on either word of mouth, or discussions heard from family and other community members. Christopher also noticed that members were describing different types of bullying (e.g. physical and verbal abuse), while others were equating bullying with burglaries and assaults.

To organize this data on the map, he created different pinpoints colors based on types of abuse. Red pins were for “physical abuse” and green were “verbal abuse.” By expanding the definition of bullying into these categories, he felt that patterns can help educate community members on abuse/crimes and where these occurred.

This experience in engineering with community showed that community knowledge(s) can be co-constructed, and that geographical knowledge(s) about spaces should be built with the community members who frequent them. Christopher with his app wanted to challenge the normative views of his community by centering his communities' experiences with the app development.

SUSU and SUSU 2.0: Expanding counternarratives of how to use technology for and with community. Ultimately the ethnographic data collected allowed for Christopher to center community as part of the app interface. In them, he included the final GIS map with pinpoints of locations he gathered through his second and third pancake layers (called BullyNET). He also integrated a Bully Survey where people can include places where people have been bullied similar to the first "are you being bullied survey." His belief is that members will now know the intersections based on their use of the map on the app, and by having a place to crowdsource the survey data, he and those that continue using SUSU, can update the GIS mapping information. SUSU also includes other options: Bully News, an RSS feed from the national StopBullying.gov website, and I'm Da Map, which is meant to show your physical location on the GIS map. The layering of community ethnography data and using this to engage the community in preventing and eradicating bullying became a dialogic-educative tool for his community.

In addition to his app interface, he also used his multimodal case as an educative website for others to learn about how to stop bullying where he states:

> Helping people be nice to other people (designing solutions) is the right thing to do even when someone around you is not doing it. it doesn't matter what other people think, you

> do the right thing no matter what. My app would help with doing this by showing you what happens every day to people that gets bullied and maybe you will change your mind about bullying someone else (Helping people be nice to other people, Weebly page).

Ultimately, this engineering design created expansive opportunities for Christopher. He first wanted to use the internet as a tool to spread love in his case, he focused a lot of his attention to building narratives around love, care and compassion for others so that this became a culture underpinning in his community. In addition to the tools of the app, he also wanted to build communication between community members in ways that previously they did not get a chance to share. He also wanted to center community knowledge(s) as part of building the app. Without community and his friends, Christopher believed the app would not exist. Lastly, he wanted to use the platform of technology as a counternarrative to the ways technology is used to control and exclude people. His experiences online in places like Facebook, Twitter, and other social media platforms have become detrimental to youth, especially minoritized youth. One of his friends, who took their own life as a result of this type of bullying centered in him the importance of using technology as its own counternarrative against bullying. Table 3.4 discusses Christopher's counternarratives, expansive learning and movement of resources in his case.

Table 3.4:
Christopher's Counternarratives, Expansive Learning, and Movement of Resources in his Case

Youth design	Community Problem Design was Solving	Experience in After School Program Related to K-12 Experience	Counternarratives of Culture of Power in Science based on Cultural, Home & Schooling Experiences	Expansive Learning Outcomes	Resources Moved
Christopher created SUSU	Bullying was a problem in Great Lakes City. Friend took their own life as a result of bullying He wanted to take an "action instead of a reaction" to bullying Bullies took situations online to classrooms and teachers would be bystanders in the process.	Bullies took behaviors online to school. Teachers did not know how to handle situation. Oftentimes boys were bullied more than girls and giving less opportunities to overcome bullying situations In science and engineering, youth were often not given credit for working together and he wanted to make sure that his engineering design credited his friends and his community members	Wanted to use technology tools used to bully as its own counternarrative to stop it Took experiences working with Big Brother on technology and legitimized his experiences in after school club Teachers did not take up Christopher's knowledge(s) of technology. Needed to center co-construction with friends to make case that he in reality did do the design Created app with community through series of pancakes Centered knowledge(s) of Black community through experiential knowledge(s) of bullying and geographic locations in community Used words such as love, compassion, care to build community amongst Boys of Color	Created SUSU with elements that supported what he wishes to see in his community. BullyNET provided a space to share positive messages (as a counternarrative to Facebook and Twitter which are used in the same ways but for bullying purposes) Created multimodal case study as an educative tool to learn about love, care and friendships Developed SUSU 2.0 by challenging social media platform's lack of prevention of bullying	Personal bullying experiences Community (valuing co-knowledge(s) sharing in community; valuing comradery between Boys of Color; centering community knowledge(s) as important to engineering design) Care (elements of love, care and compassion as important staples of youth in schooling experiences)

Discussion

Creating these cases became a source of strength that challenged normative views of science education, particularly in unpacking what knowledge(s) and practice(s) count in science and for whom is science for? All three-youth discussed important problem spaces that were addressed by their designs and how these became *counternarratives of culture of power in science.* The expansive learning of these counternarratives allowed to see how they were tied to family, home, and community practice(s) in other areas of their life.

In the following section, I share a cross case analysis of AD, Faith and Christopher's cases in regard to the two main claims of this study.

Generating Counternarratives of Doing Science and Engineering through Community in the After-School Green Energy Program Supported Youth in Being More Critical of their School STEM Experiences and Created New Opportunities for Authoring Hybrid Practice(s) Involving Family, Community and Other Education Pursuits

In all three cases, generating counternarratives of doing science and engineering in community through the after-school program supported the youth in being more critical of their school STEM experiences. These then created new opportunities for authoring hybrid practice(s) involving family, community and other educational pursuits.

The common link regarding the co-created cases is that participation in the after-school club supported youth in doing science that matters to them and their community. Through this end, they were able to find meaningful ways to merge their interests, views and purposes of science in the ways they found meaningful in their communities in how the youth identified problems and designed solutions (NGSS engineering design practices). In addition, these stories provide important counternarratives to the settled expectations (Bang & Medin, 2010) of science learning and expanded what it means to do science in/with community. This expansive learning made their counternarratives ever more powerful in supporting meaningful science learning experiences for minoritized Youth of Color in STEM education.

Counternarratives in centering resources when defining problems. AD's counternarrative regarding resource availability and economic effects of using materials were evident in her bringing her duct-taping expertise to the club. One that was already being legitimized by friends outside of school. Because of the economic situations that she has experienced with her father losing his job, she has made tough choices regarding what types of materials she can focus on in her designs. Moreover, as a teenager experiencing new and changing fads, she has had to use materials that are cheaper and easily accessible. Thus, her use of duct-taping merged as an economical counternarrative to materials that engineers may use in addition to centering herself as an engineer because she makes with duct-tape. A type of accessible material.

In using duct-tape she is also centered her personal economic struggles and legitimized other youth's personal and economic counternarratives by connecting to broader economic issues evident in Great Lakes City. More specifically, AD was aware of the racial and classist effects that the local economy had on her and her father's life, and then this experience transcended over to issues of being able to afford materials including duct-tape, but also beauty products that she needed for her daily use. In centering the use of *her* duct-tape she was challenging the affordability of science materials in classroom spaces, while also challenging what, who and in what ways science/engineering can be done.

AD's use of duct-tape as an economic challenge to what materials can be used in engineering design centers and challenges the traditional views of resource equity in science

(Tate, 2001) as a way to create access to the field for youth. Oftentimes, conversations about equity in science is related to “sharing of resources, or equity in classroom spaces” (Tate, 2001) but ultimately, AD’s experiences showed her that not only do youth need to center materials and resources which she and her community members could afford, but also that these materials are significant in the lives of youth and how they bring their knowledge(s) and practice(s) already legitimized in community to their science learning. Her history with duct-tape, her knowledge of electrical engineering and connecting wires and her passion to create “a duct-tape fashion company” already made AD an engineer. In centering herself as an electrical engineer with the materials she had readily available such as duct-tape or electrical tape (in her conversation about who is an Engineer) became a source of strength. In addition, her knowledge of using coconut-oil to create community-centered products challenged how science can be used in ways that can further exacerbate income inequities between businesses and Communities of Color that use their products, even if they have good intentions. AD’s direct challenge to re-purposing materials and resources in ways that upheld legitimized knowledge(s) and practice(s) of youth supports AD as creating a new, hybridized view of what it means to create an equitable, community-centered science education for youth, especially in her same circumstances.

On a similar note related to materials, Faith brought her Grandmother’s problem space from Florida into the club. Her goal was originally to make a church hat, but then in her multimodal case, Faith expanded this notion to center the FANcy hat as an emotional, and cultural historical symbol of community resistance, uplift and education regarding views of climate change and sun exposure in the Black community.

The after-school club provided many options to center Faith’s design (e.g. watching YouTube videos, asking her near peer mentor to bring in a type of hat). However, did not want to use any of those hats or designs. She wanted to center a hat her community would use and the way she did this was by critically engaging her community throughout her design making process. With community members (including her family and other youth at the Community Center) she tested various ideas including the hat with the propeller on top, the fluffy hat with earflaps and two types of baseball hats and brims. She also asked youth to test the different types of hats with different sized solar panels to see how style and functionality could be merged together to make it a wearable accessory. In this case, settled expectations in science were challenged by the ways Faith purposefully created opportunities to further explore ways that her family and community needs could be merged with the hat. Her Engineering Design cycle in Figure 3.12 shows how she continuously questioned how community problems were being iteratively solved throughout the engineering process, rather than just settling on one solution and building from that solution such as what is called for in the NASA cycle in Figure 3.13.

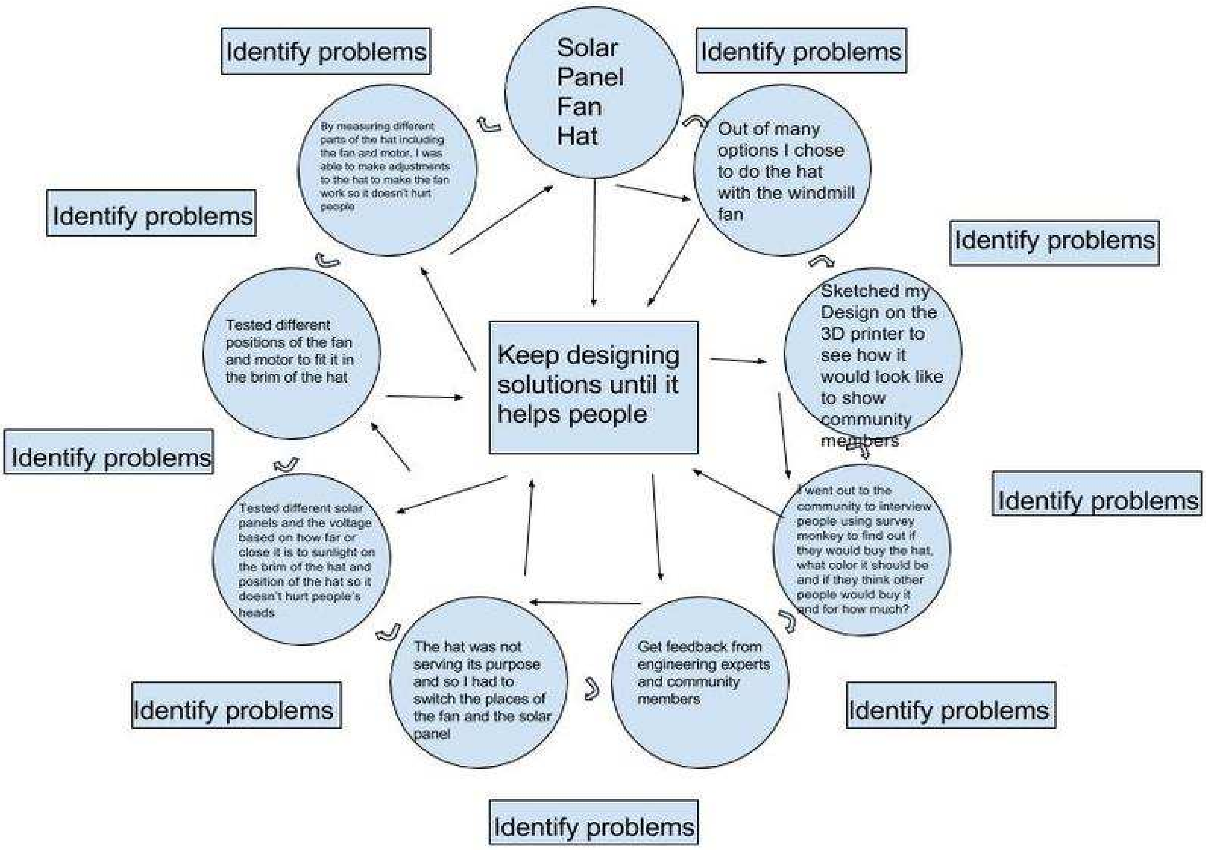

Figure 3.12: Faith's engineering cycle with community.

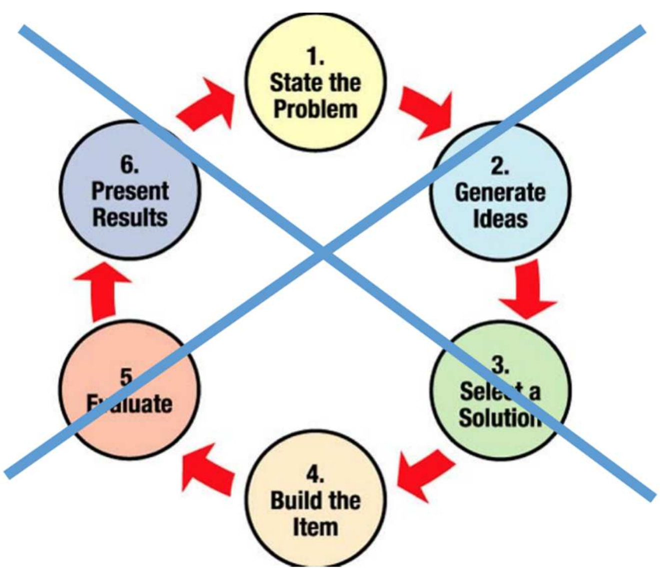

Figure 3.13: NASA engineering cycle crossed off by Faith on her case.

Christopher’s centering of resources was twofold. The first was related to his use of an app as a counternarrative to what counts as engineering. He had many opportunities to create designs that used tools in the makerspace, but instead he centered the design on a technological application which required community input as resource to co-construct and design. The second was related to using technology as a counternarrative tool for bullying. His goal of creating an app was to use the different tools of the app to counter narrate the ways those same tools in other technological applications may be used to bully others. For example, in creating the Bully Wall, he is offering members of his community a space for dialogue about love, care and compassion. These are the same methods used by Facebook engineers who create “walls” where people could comment on one another. However, Christopher noticed that many people spread hate by sharing negative memes, videos and opinions about people, places and things. The settled notion of science here is seen in that engineering (and what it means to engineer) can become much broader and can include community-building in positive ways. Christopher engineered his app with his community, so that they too created with him the uses of his app. He did not want his app to be created by an outsider and used in ways that were not central to solving the problem of bullying. He wanted to challenge the ways Facebook and other technologies have been used negatively to spread hate within communities.

Counternarratives in centering community beyond designing solutions. One of the most important ideas in cross-case learning related to counternarratives of the culture of power in science was related to youths’ centering of community needs during the design process led to further solutions and learning for their communities beyond their designs such as centering community knowledge(s) and practice(s) in their designs and expansively over spaces (community, after school, school) and time (impacts on middle school, high school and learning beyond the after school green energy club).

AD's duct-tape thermometer tie was one solution to solve potential issues in community related to the onset of the Ebola virus. She did not want her community to suffer the same economic consequences she and her family endured after her father became sick from his respiratory illness. Her creating a duct-tape tie created opportunities to bridge multiple learning experiences beyond just its design. For example, her duct-tape tie evolution (as she noticed the ways she created designs over time) connected in important ways to how she viewed herself as evolutionary in her making experiences. These experiences were tied to how she started as a learner, then as a maker and then as a community advocate. As an advocate, she made science learning accessible to her community through creating YouTube and Facebook Live videos on teaching others about scientific related economic choices. She did this by centering her experiences making the tie and centering herself as an engineer throughout the design process. For example, she challenged the ways companies like *Shea Moisture,* although have the best intentions in marketing their products towards the Black community, these became less affordable and the more reliance on these products the less community members would learn to use their own scientific knowledge to make them.

Faith's centering of community and shifting of practice(s) beyond community involved ways she centered her hat as a design for the community as she viewed how it would solve varying problem spaces. Her hat for example could be used as a way to center church as power community spaces for members of the Black community in Great Lakes City. By having Grandmothers wear their elaborately decorated church hats, including the FANcy hat, then these spaces become centered because more people would wear their hats and go to church without fear of getting hot and sweaty. In addition, she wanted to educate community members on the dangers of cancer-causing sunlight rays, while also helping them to save energy by harnessing the energy of the sun. She did this by connecting her solar panel house experience to the ways batteries were used at home (e.g. her brothers' use of their Wii remote) and then taking this perspective back to her church with harnessing the energy from the ceiling windows. At the end, centering her community meant using the FANcy hat as an educative tool for its multiple purposes in solving problems in the community.

In Christopher's case, his centering of community involved viewing his community members and friends as co-developers of the app. Coincidentally, friends and community members who he designed the app for attended the same school and had similar bullying experiences as he did. In addition, he saw that teacher's lack of interest in mitigating bullying in the classroom created broader issues which by including his friends in the co-design process, he could educate them on and support a culture of taking an "action instead of a reaction." Hence, by co-sharing of knowledge(s) and resources, he is also sharing the claim of his SUSU design. This is an important aspect of survival in his community. One that became a counternarrative in centering community beyond the SUSU design.

Counternarratives of K-12 science learning experiences. One of the most important learning opportunities regarding counternarratives that the youth described in their cases was related to K-12 learning experiences, and how they were viewed in their classes in particular. Across these cases, the three youth directly countered the epistemological practice(s), and epistemological narratives that drive their experiences in school. For AD it was the role of her experiences for epistemic building blocks were important to her learning, for Faith it was how learning engineering through community was not the same for everyone and for Christopher it meant centering app making and knowledge(s) of technology as one type of STEM learning.

AD’s unpacking of the building blocks related to her schooling and out-of-school experiences as part of her multimodal case became counternarratives to the epistemological practice(s) and epistemological narratives related to what it means to learn in school science. She described this in two ways. The first was how her teachers depending on the subject, would focus on different aspects of Lucy (the Hominid’s) story. In history, she learned about Lucy in ways that humanized her existence and allowed her life and struggles to be seen as evolutionary, but in science class, Lucy was just an example of how one animal evolves from a hunter-gatherer through natural selection. Connections in science did not connect to Lucy’s humanized experience or how her sense of survival related to her community members or the existence of her entire species. This settled nature of science created tensions in AD’s view of who she was as a student in her science classes and how she could humanize her experiences in these spaces.

Particularly, AD discussed that science and predominately in the ways science is taught to students is racist. She noticed clear differences in the disciplinary connections to ways science can be humanizing and/or dehumanizing depending to who has access not only to using materials to engage in science work, but who gets taught the knowledge to use it positively in their communities (e.g. knowledge about coding and computer typing). She contrasted this view with connections to ways science can be used to controlling and even limiting economic pursuits of communities (buying *Shea Moisture* but not getting taught or supported in making your own products). She discussed in one of her interviews that if science is the study of the world “around us” and how things change and how one can notice and wonder why things happen, then why don’t students get taught to view things as changing and to notice and to wonder. Instead students are taught to not study the world around them and not wonder and notice why things happen (Interview 2).

AD noted that teachers in her biology class focused on worksheets and did not consider the types of learning AD wanted to see for herself. She wanted to see more hands-on activities and applications for her learning. Instead it was pages and pages of worksheets that never connected meaningfully to her life. Hence, she discussed that youth "are programmed to have this life" as an important point in AD's case. She noted that youth, especially Youth of Color are seen in society and education for the purposes of being programmed. Economic, social and political decisions were already made for them and taking a counternarratives lens helps us to further unpack why this is directly connected to the colonialist, racist and settled notions of science that AD describes. This economic and political learning connected to the economic decision-making regarding literacies that then in turn affected the ways they made, or participated in These experiences prompted AD to begin educating her community members so that they become critical in the economic choices they make. She created YouTube and Facebook Live videos for her community members which then were merged to her interest in teaching teachers about the challenges of Youth in K-12 so that they learn to teach from youth' experiences.

Faith's main counternarrative to K-12 science learning was related to the epistemic tools that educators use to teach science content. In the after-school club, the mentors centered teaching about engineering design practice(s) using the NASA cycle. However, Faith had great trouble trying to map her design process on the cycle we provided. Instead, she decided to author her own cycle and iteratively document the process she took to center community problems and perspectives as she found ways to design solutions through the engineering year. Ultimately her learning from centering community in her design cycle taught her about the challenges related to engineering design that are implicit where there is an intentional erasure of community knowledge(s) and practice(s) in science content taught in schools. She noted that the NASA cycle, which only details an easy, straight-forward process "washes over the real" (Interview 6) scientific processes that engineers use to make designs. This washing over is epistemological, methodological and ontological where racist notions of what knowledge counts, in what ways can knowledge be used and how that knowledge supports changes in communities become erased and further exacerbates the dehumanization of minoritized communities towards legitimizing what they know within the established culture of power in science. Taking the culture of power as a settler logic, we see a primarily individual focus in the settled notion of science. However, Faith here is pushing towards a community-centered logic in engineering design—one that directly challenges what it means to do science, with whom and for whom?

Combining the experiences in engineering for community, whose stories and experiences were not part of the NASA engineering cycle, she decided to connect the process of engineering with tools and practice(s) she used to make for her community to the therapeutic discipline of psychoengineering. By building sculptures and other resources with tools of engineering and harboring those feelings in the designs created, community members can release what they feel through these designed sculptures. This was especially important in helping her mother overcome her experiences being a victim of racial discrimination at her workplace. This counternarrative was essential to the settled notion of science learning and materials which are often reduced or removed in ways that don't center the real, detailed design process of community. Instead these reductive practice(s) can limit the critical movement and understanding of the design process for youth learning this in K-12. This limiting and reductive nature could become a limit to the cultural capital needed to learn about methods of engineering design for minoritized Youth of Color. In Faith's case, she first challenged the settled notions of the NASA design cycle and through these tensions needed to author new ways to include their views, purposes and action-taking in their science learning.

Christopher in his work challenged the ways teachers limited interaction with bullied youth and reinforced bullying behaviors in the classroom. He also noticed ways that teachers did not legitimize Youth of Color's experiences and how bullying between boys was not challenged and mitigated in the same ways as girls bullying experiences in his science classroom. Hence, he counter narrated these experiences by building comradery with his Black friends who were also bullied in the same classroom by giving them credit on the design on his multi-modal case, and by challenging notions of toughness and lack of empathy that are associated with boys' performance in school. He did this by centering his case on educativeness of love, care and compassion in his community.

In the next section, I describe the second discussion point in this chapter.

As Youth Authored Multi-Modal Cases to Teach Others About Their Designs They Also Sought to Teach Others About the Culture of Power in Science by Highlighting Their Counternarratives as Critical to Their Design Work, Leveraging Multi-Modal Ways to Communicate Ideas and Making Them Accessible to Community Members and Foregrounding Designs that Work to Prevent Systematic Oppressions and Promote Active Participation in STEM Community

AD, Faith and Christopher in their multimodal cases sought to teach others about their engineering designs and the culture of power of science by highlighting their counternarratives as critical to design work. In doing so, they communicated important ideas that could be accessible to community members and important others as a way to prevent systematic oppressions and promote active participation in the STEM community. They did this by 1) highlighting their counternarratives in the multimodal cases, 2) the cases made counternarratives and critiques they addressed more broadly accessible to the community and 3) finally the youth used their cases to teach others about how to challenge settled notions of K-12 learning by supporting expansive educative opportunities for meaningful others.

In highlighting their counternarratives in the multimodal cases, all the youth in the creation used the Weebly platform and the tools accessible through this platform to narrate their cases. At the end of P1, I wanted to document the engineering design process they took in creating their "inventions," however, many of the discussions the youth and I had were related to counternarratives youth wanted to tell related to their participation in the green energy program. Hence, through gathering all the multimodal data in P1 to better understand the engineering practice(s) they leveraged in creating their design, we instead moved into creating e-portfolios which became data sources for P2 of the study. Using data from P2, we decided to tell these multidimensional and multifaceted stories which then needed an online platform to showcase. The youth-centered how their stories needed to become educative for others through "a platform" that would allow critical sharing of ideas youth produced through unpacking audio, videos and artifacts during their design creation. Hence, we took these critical connections to the sources in P1 and merged them into a Weebly page which became data for P2.

The naming of their websites and the pages within the Weebly became very important in connecting counternarratives of their K-12 and making experiences to the e-portfolios they created. Hence, they detailed different counternarratives through ways important others (e.g. community members) could relate to them through the ways they discussed their engineering work on the websites. Choosing name such as: Something so small can become something so big (AD), Imagination creator (Faith) and Speak up step up is somewhere you know, somewhere you want to go (Christopher) became important intersections between the meaningful science stories they wanted to tell and connections of why these are important to community members. Table 3.5 connects the multidimensional counternarratives with the naming of these in their stories and how these connected to systematic views of science.

Hence, youth used their cases to teach others about how to challenge settled, but also colonizing notions of K-12 learning by supporting expansive educative opportunities for meaningful others through the stories told in their cases. In using the Weebly platform, stories became real through the engineering design artifacts (e.g. videos, text, uploading pictures and decorations they could add to the text throughout their inventions) they merged with their counternarratives. Ultimately, these counternarratives critiqued, addressed and systematically unpacked the importance of their inventions for, with and by their community. By supporting a critical view of their science learning, the youth oftentimes recognized as being systematically oppressive through how they felt it was not supportive of what they knew, their family and community practices and the ways they identified and the science they wanted to do. Through the cases, they did this by upholding counternarratives of the culture of power in science, and directly and systematically challenging the oppressions and promoted their participation and those of their communities in STEM through what they chose to include in the cases themselves.

The youth also took these expansive teaching opportunities for others into new critical connections with economic, political (power), epistemic and historical shifts needed in school science learning, what engineering is, who can claim engineering, and for whom it can be used in the community, but also how engineering can also be colonizing if not done and unpacked in the right ways that legitimized community problems, practices and expertise(s) (like in Faith's case with the NASA cycle). The multiple counternarratives of the culture of power in science positioned the cultural, political, economic, epistemic and historical ways science has been done and done onto minoritized Communities of Color. First, these collective cases noted how culturally, science learning is settled and removed from youths' views and purposes of science (reasons for making designs, how community was centered in the design creation) but also science learning does not center ways youth are everchanging and evolving (in the same ways that problems in communities' change, learning also changes) and how science needs to leverage community knowledge(s) and practice(s) over space and time.

In Table 3.5, I connect these themes in the cases to the ways youth wanted to educate others in support of a science learning that supports community knowledge(s) and practice(s) and systematically can leverage these knowledge(s) and practice(s) towards counteracting oppressive systems that science learning has reproduced for them in their learning.

Table 3.5:
Connecting Counternarratives of Culture of Power in Science to Supporting Meaningful Learning Opportunities for Others (e.g. PSTs

Youth and Design Work	Ways youth wanted counternarratives to challenge systemic views of science	Connections in Weebly Page	Ways these Counternarratives can support meaningful learning for others [e.g. PSTs]
AD and her duct-tape tie	Resource availability in school settings (e.g. duct-tape) Settled and colonizing views of science knowledge(s) and practice(s) limited opportunities to expand on past and present learning (e.g. Lucy, tech connections) Questioned overreliance on textbooks as a form of learning. Centered need for experiences connected to how she wanted to do science (hands-on, related to after school program) Not being able to express science and engineering learning created tensions (e.g. writing poetry as a form of expression) Making in science is connected to money. Minoritized communities are not taught to read and be critical of labels of products, which causes them to become dependent and lose economic capital. Connected scientific literacy to economic-decision making. She viewed science as racist.	My Invention (AD discussed her duct-tape design and why it is important for the community) What is evolving? Duct-Tape Evolution Teachers Learning from Students (video talking back to teachers use of worksheets during science lessons) Classroom Presentation and Feedback (connecting her 8^{th} grade science learning experiences to ways science can be learned through in high school) Helping People and why it is important to me and my invention? My evolution of inventions! And the Magic of YouTube (sharing videos with community members as a way to educate on ideas related to energy conservation and saving money) Health-related Uses of My Invention String-related inventions that can repurpose common Household Materials Multiple Uses of Coconut Oil	Providing access to science materials in classrooms is not always in line with access of materials in community Science learning is not settled, and changes based on learning about community and personal connections youth have with content Limiting text-books and reading in science and create experiences in line with hands-on or leverage experiences outside of school Provide opportunities to create knowledge(s) for communities (e.g. why learn this science? Who benefits?) Through a type of scientific literacy that is socially, economically and racially consequential

Table 3.5 (cont'd)

Youth and Design Work	Ways youth wanted counternarratives to challenge systemic views of science	Connections in Weebly Page	Ways these Counternarratives can support meaningful learning for others [e.g. PSTs]
Faith and her FANcy Hat	Created her own community-centered cycle because all designs are different because community problems and design practice(s) are different Black community are not taught the dangers of cancer-causing sun light rays (connections to scientific literacy) Engineering design experience taught her tools to overcome tensions between struggles in community and in everyday practice(s) Challenged views of community spaces such as churches as powerful places where the Black community feels safe. Hat became a symbol of safety for her community to be able to discuss factors that minoritize them (increased police presence, #BlackLivesMatter, sharing important milestones of youth in the community).	My Engineering Cycle Identifying Problems (connecting problems of community through the engineering cycle) Designing Solutions (ways Faith iteratively moved community through her design process) My Invention (connecting the multiple problem spaces to her invention) Psychoengineering (text and video explaining the importance of psychoengineering) About Me (connected herself through her community in relation to her design work and problems she was trying to address).	Ways material is learned in the textbook or through sources online can be adapted based on problems and perspectives of youth or how they view community connected to science learning Provide opportunities to create knowledge(s) for communities (e.g. why learn this science? Who benefits?) Through a type of scientific literacy that is socially, economically and racially consequential

Table 3.5 (cont'd)

Youth and Design Work	Ways youth wanted counternarratives to challenge systemic views of science	Connections in Weebly Page	Ways these Counternarratives can support meaningful learning for others [e.g. PSTs]
Christopher and SUSU	Wanted to use technology tools used to bully as its own counternarrative to stop it Took experiences working with Big Brother on technology and legitimized his experiences in after school club Teachers did not take up Christopher's knowledge(s) of technology. Needed to center co-construction with friends to make case that he in reality did do the design Created app with community through series of pancakes Centered knowledge(s) of Black community through experiential knowledge(s) of bullying and geographic locations in community Used words such as love, compassion, care to build community amongst Boys of Color	Introduction (introducing design to community) Helping People be Nice to Other People (outlines how community and brotherhood is important in sharing, caring and loving one another) Helping People be Nice to Other People The Behind the Scenes Look (implicating community as part of the design) Identifying Problems GPS Map Integration (co-development of engineering design with community) App Components (parts of the app that counter narrate ways technology is used without views of communities) Helping People be Nice to Other People Identifying Problems	View multi-purposeful views of science learning. It's not only biology, chemistry, physics but also technology and engineering and its uses in everyday life for people. Also, that youth can re-purpose and re-shape views of science learning by combining previously learned knowledge(s) with new knowledge(s) (e.g. combining pancakes in engineering design where one type of learning of community bullying is not mutually exclusive from the other) Legitimize outside-of-school experiences with members in the community not connected to family or friends (e.g. recognizing that a student like Christopher is in the BBBS program) Provide opportunities to create knowledge(s) for communities (e.g. why learn this science? Who benefits?) Through a type of scientific literacy that is socially, economically racially, but also gendered and consequential

Implications, Limitations, and Future Learning

In this chapter I examined youth's engineering design work and the multi-modal stories they tell about this work to make a case for how youth seek to dismantle the culture of power in science through their counternarratives. These counternarratives of the culture of power in science point towards the ways in which youth leverage and move a wide array of cultural resources from their lives into doing science that matters to them, to de-settling expectations (Bang & Medin, 2010) of what it means to know and do science, whose lives and experiences can be at the center of new scientific ideas and practice(s)—especially towards one that is anti-racist and anti-colonist. One of the most important parts of this piece is that the youth ask us to question: what is science and for whom? I suggest that these counternarratives offer critical insight into what may become types of practice(s) that are "youth-centered and equity-oriented" which can promote equitable and a just science education, especially for Youth of Color.

Important to note about this work is how CRT (and counternarratives more specifically) as a framework helped to unpack how colonizing effects of the culture of power in science were part of the youth lives. As CRT states, the theory directly challenges how race and racism are historically part of society, but it also aims to eliminate other forms of subordination (e.g. gendered, classist, disability status, etc.…). Although there was not enough justice done to the work of the youth in regard to race, the framework of counternarratives allows to directly challenge normative and settled notions of science through a lens of experiential learning of the youth—which was one of the main goals of this piece. For future research, it would be important to focus more on race and racism as part of how it functions within the bounds of reproducing a culture of power in science by unpacking more directly the effects of race and racism in science learning in their in-school and out-of-schools science experiences.

One of the main learning points from this work is that it leads towards centering what it would look like to support youth-centered and equity-oriented practices in science. Practices that directly challenge the culture of power students know exist in their lives. These practices need to be concerned with de-settling science teaching and learning, but critically transforming the ways culture of power have delegitimized knowledge(s) and practice(s) in science learning for youth in minoritized communities. Especially in that learning about community and personal connections youth have with content are important to ways youth connect with science learning, but also that they critique the connections that they see between the discipline and their lives authoring a new way to view science that is not colonialist, settler, but also transformative and sociopolitical in centering communities rather than individuals in knowledge-making of science knowledge(s) and practice(s). In addition, these practice(s) provide access to science materials that are true to the materials they can use and re-purpose in their communities. These practice(s) also look at limiting text-books and resources already created for youth to learn from that do not necessarily connect to youth lives and pursuits and ways they see meaningful science learning. The youth want science experiences that are connected to youth lives and their communities by interrogating: what is science, why learn it and who benefits—ultimately creating a type of critical engagement with science that is racially and socially consequential.

At the same time, this approach asks to recognize the education debt and that educational outcomes are inherently tied to ways youth are minoritized, historicized, politicized, racialized in society and in in their schooling (Ladson-Billings, 2006)**.** Youth in their cases wanted to shift views of science in ways that were multi-purposeful and co-created with community. That science is not one definitive answer, but multifaceted, generative and iterative in its becoming and most importantly in its learning and its use for minoritized, Communities of Color.

YCEO practice(s) call for shifting stereotypical and essentialist notions in equity goals of science. These cases also provided new and expansive ways centering multimodality as a type of literacy that can help others learn about the scientific practice(s) they engaged in. By creating videos and other text and tools, youth were able to author new and expansive ways to center their counternarratives to the culture of power in science—and theoretically combining these into creating new YCEO practice(s) can help us to view the ways these can be expanded to other local practice(s), like classrooms or PSTs learning.

In taking an assets-based, disruptive stance and critical implications of this work, I am not just seeking for others to view these practice(s) in relation to youth science learning, but that these practice(s) recognize and disrupt systems of oppression towards centering youth counternarratives of the culture of power in science as a tool to advance equity in science education. In the next chapter I take up how these YCEO practice(s) might inform beginning teacher learning by developing a methods course that supports PSTs to imagine and generatively support a more youth-centered, equity-oriented teaching approach in their teaching/field experiences.

CHAPTER FOUR:

SUPPORTING YOUTH-CENTERED, EQUITY-ORIENTED IMAGINARIES IN A SCIENCE ELEMENTARY METHODS COURSE

Science can be seen as many things. Whether it is teaching in [a] classroom or at home, it is useful to connect it to the world around us because science really is all around us. To teach science well, it is important to reach out to all youth. Providing youth with different options, I think, is a huge part of getting youth excited about what they are about to learn. Teaching in an equity-oriented way is important in the classroom. This is so that all youth are provided with individualized equal opportunities to learn and succeed--Sarah, a preservice teacher describing good science teaching

Sarah's quote is one preservice teacher's view of describing good science teaching. Here, she discusses that science is seen differently by youth and that engagement with science can happen in various spaces (at home, school, community). In providing youth with varying opportunities to learn in ways that best excites them, Sarah feels this could lead towards equitable science teaching. Sarah and 21 other elementary education students participated in the course, TE 400 at Midwestern Research University (MRU) focused on teaching science to diverse learners. This course supported PSTs in developing ways to engage in/with culturally responsive science teaching in equity-oriented ways foregrounding the critical uptake of youth-centered knowledge(s) and practice(s) as important in preservice science teacher education.

Problem Space

Over the past two decades, PST education has seen remarkable amounts of policy directed towards improving and preparing the best, most qualified teachers to teach America's diverse student population. Yet, in the United States, academic concerns over contribution of teacher education to broader educational outcomes has been called into question (Levine, 2006; Stroupe & Gotwals, 2018; Zeichner, 2010). Because the "work of teaching" (Ball & Forzani,

2009) is often contested, debates exist as to what practices best contribute to a teacher's success in our nation's multicultural, multilingual, and multiethnic classrooms. For the most successful educators, their capacity to teach grows out of a professional repertoire that is "complex, relational, grounded in deep understanding of subject matter, and adaptive to learner's needs" (Windschitl et al., 2012). It is also known that this type of trajectory is not always supported by teacher education programs (Windschitl et al., 2012). With practices being at the core of teachers' professional development, recent calls ask for teacher education to become grounded in practice (Ball & Forzani, 2009; Darling-Hammond & Bransford, 2007; Grossman & McDonald, 2008).

Many material activities and reflections focus on how these future teachers learned themselves as youth (Levin et al., 2009). However, it is important that PSTs understand how to engage their future youth in ways that are youth-centered and equity-oriented, and they need support in developing these practice(s) early on in their learning to teach. Cochran-Smith and Lytle (1999) discuss how the teaching profession is forever tied to the purposes of schooling and educational change--where these are driven by continuous re-definitions of policy, research and practice(s) in classrooms and schools. I argue for a type of learning to teach that focuses on developing pedagogical imaginaries towards these (re)definitions of purposes of science learning towards equity. These imaginaries can become conceptual space of development, where there is constant disruption of work, rules, subjects and puts limits on tools in schooling (Dominguez, 2015) allowed for a place to "see" something that is yet to be developed or realized (Dominguez, 2015). Being able to relate to the classroom communities they view in their field experiences through a lens of supporting youth knowledge(s) and practice(s) can be a new practice(s) -based approach in supporting equity in preservice science teacher education.

The research questions for this study are:

1. What pedagogical imaginaries do PSTs hold of youth knowledge(s) and practice(s) in their learning to teach of science?
2. How do these pedagogical imaginaries inform their initial views of youth-centered, equity-oriented science teaching practice(s)?

Foregrounding Youth-Centered Equity Concerns in Science Teacher Education

Inequities in educational attainment and participation in science continue to persist for minoritized youth in the United States (NSF, 2014). Challenges to youth science interest, motivation and engagement are most critical in the transition between elementary to middle school (Tan et al., 2013). These challenges include connections between factors, such as engagement, interest, school contexts and culture, classroom pedagogy, peer influences and home environments in their learning (Carlone et al., 2014). Together, these limited opportunities to high quality academic preparation in science has limited youth access science-related career choices (NSF, 2014). If youth are to achieve in science—and pursue STEM trajectories—they need opportunities to enact their views and purposes of science to their lives/ educational pursuits and the social relationships they value (Basu & Calabrese Barton, 2007).

With calls for supporting learning of science/engineering disciplinary core ideas and practice(s) based on the *Next Generation Science Standards* (NGSS Lead States, 2013) and the concerted attention to derive and advance ambitious and high-leverage teaching practice(s), (Jackson & Cobb, 2010; Windschitl et al., 2011) teacher preparation has become a focal point in the science education debate. It is necessary to support teachers in “habits of mind” to learn from practice(s) as they enter the profession (Borko, Jacobs, Eiteljorg, & Pittman, 2008; Grossman &

McDonald, 2008). Using evidence of experiences in learning to teach over time can help support increased attention to equity in classroom practice(s).

Windschitl and Calabrese Barton (2016) discuss that frameworks are needed which "valu[e] the heterogeneity of youth' backgrounds, ideas, and ways of communicating as resources for instruction" by centering equity concerns in how teachers develop systematic cycles of inquiry into practice(s) (Windschitl & Calabrese Barton, 2016, p. 576). I argue for a type of framework that is generative in its development towards systematically putting the methods course in conversation with the field in which teachers learn to teach. By centering pedagogical imaginaries in methods courses that allow for unpacking multiple cultures, languages and repertoires of youth in their field experiences, PSTs learn to develop these systematic cycles of inquiry into practice(s) early on in their teacher learning.

Defining Youth-Centered, Equity-Oriented Science Teaching Practices

Learning to take up youth funds of knowledge(s) (Moll et al., 2005) and repertoires of practice (Gutiérrez & Rogoff, 2003) is central to developing the kind of pedagogical imaginary focused on equity that I mentioned above. In particular I am interested in how this uptake supports PSTs to imagine youth-centered, equity-oriented practice(s) in their learning to teach.

Practices in teacher education are the beliefs, ideas and methods teachers bring to their classrooms --currently a very important area of study in preservice teacher education (Windschitl et al., 2012). Practices are never neutral and are tied to culture. In classrooms this is especially true because of the varying contexts and social situations that exist within them. By focusing teacher learning and practice(s) development from youth funds of knowledge(s) and repertoires of practice(s) calls attention to how science is deeply rooted in the histories and geographies of young people, where science involves broader social and community concerns (Birmingham et al., 2017).

In Chapter 3 of this dissertation, I studied the ways three youth discussed their *counternarratives of the culture of power of science*. These counternarratives served as examples of the milieu of ways youth sought to disrupt systems of power and oppression in their classrooms/out-of-school and community settings based on types of cultures reproduced in science education. Taking the learning from the previous piece, I have conceptualized a new way to support teachers in taking on youth-centered views of science teaching and learning in equity-oriented ways.

Hence, in conceptualizing *youth-centered, equity-oriented practice(s)* (YCEOs) in science, it is important to first focus on (1) how culture of power exists in science teaching and learning (Calabrese Barton & Yang, 2000); (2) teacher learning should be deeply connected to the histories and lives of young people (Ladson-Billings, 2001; Nieto, 1999); and 3) how youth's funds of knowledge(s) (Moll et al., 2005) and repertoires of practice(s) (Gutiérrez & Rogoff, 2003) can be legitimate resources for science learning. Altogether, in combining these youth-centered, and equity-oriented views of teaching and the uptake of youth histories, lives, and possible futures in shaping disciplinary knowledge(s) and practice(s) of the scientific community—in advancing new forms of knowledge that end the injustices embedded in current forms of knowing in science.

Youth-centered, equity-oriented teaching practice(s) recognizes and positions youth as social change agents in their learning (Gutiérrez et al., 2017). At the same time, this approach asks teachers to recognize the education debt and that educational outcomes are inherently tied to ways youth are minoritized, historicized, politicized, racialized in society and in in their schooling (Ladson-Billings, 2006) and particularly in science education. In taking an assets-based, disruptive stance and critical implications of this work, I am not just seeking for teachers learn about these practice(s), but that they engage in them and develop their methods of these in ways that disrupt systems of oppression in science classrooms, an idea critically needed in science teacher education.

Using this framework, I co-developed a course, TE 400: Teaching Science to Diverse Learners which focuses on supporting this uptake of youth knowledge(s) and practice(s) in science teacher education.

Theoretical Framework: Imaginaries as Practice

In the next section, I discuss a social practice approach to teacher learning through supporting pedagogical imaginaries in practice-based teacher education. These will combine to form the theoretical framing for this paper: imaginaries as practice.

I draw upon social practice theory (Holland & Lave, 2009) to initially guide this study. Holland and Lave (2009) discuss that social practice theory "integrates the study of persons, local practice(s) and long term historically institutionalized struggles" (p. 1). I chose this theory because of its potential to "understand[ing] and explain[ing] real, every day, situated activity in its concrete, material detail" (Roth, 2006, p. 22) while also "emphasizing historical production of person in practice(s) and pay[ing] particular attention to differences among participants, and to the ongoing struggles that develop across activities around those differences" (p. 1).

Holland and Lave (2009) refer to "two forms of history," the personal and institutional. The authors argue these forms of history, "history in person" and "history in institutionalized struggles", are always present and in relation through the activities individuals participate in. Hence, these histories are carried out via personal experiences in local practice, and in turn are enacted against the broader cultural and historical narratives in which they occur. In this chapter, I want to understand how PSTs ' history-in-person (in ways they view their K-16 science learning experiences and hopes for teaching science) interact with generative development of youth-centered, equity-oriented imaginaries as they develop knowledge(s) about the field and its interactions within topics learned in the TE 400 methods course.

In order to better understand how social practice theory influences the ways teachers imagine developing practice(s), it is necessary to unpack the conceptual idea of pedagogical imaginaries. Pedagogical imaginaries (taking from Dominguez, 2015) are fluid, conceptual spaces that can support comfortability of perspectives involved in a classroom exchange. They involve the practical realities and emotions involved in interactions between teachers and youth and can be mediated and (re)mediated within these problem posing, fluid spaces. By this, I mean that a problem-posing, fluid space like the interaction between views of youth in a methods and the field, can become places to support PSTs in unpacking the practical realities of schooling without the pressure of interacting. Rather, PSTs can generatively develop imagined views in science teaching through how they see their personal views of science teaching interacting with the ways these see this science teaching occurring in practice(s) . This is done by recognizing connections between theory, supported through a methods course, and the field, as practice(s).

In generatively shaping and re-shaping these practice(s) through imaginaries the teacher learning here becomes transformative through its constant re-mediation in spaces of fluidity (Dominguez, 2015) and movement of resources including knowledge(s), tools, and (re)negotiations towards meaning-making. This primarily is done through how PSTs view youth in their field classrooms and how they generatively imagine teaching practice(s) to in support of those youth.

Combining Dominguez (2014) and Laudo Castillo's (2014) framing on fluidity helps to challenge the solid method in educational exchange which is often taught in methods courses. Rather than viewing teaching as a one-way exchange between a teacher and individual students, in this methods course, PSTs are supported in developing emerging views of science teaching alongside their views of communities in the field. The tensions in these interactions become fluid and can change depending on how PSTs see tensions arising in local practice from the multiple perspectives and relationalities between the youth in the classroom and their field teachers. These then become spaces to re-imagine practice(s) that can become generatively youth-centered and equity-oriented.

By challenging the solid method of exchange, I am challenging the hidden curriculum that reproduces the culture of power in science. If these rules and conventions are not unpacked through a cultural and historicized lens of how youth see themselves, their purposes and views of science learning, then PSTs may not have the opportunity to view the settled nature of science (Bang & Medin, 2010) and ultimately shape their teaching over time to eradicate these settled notions in their practice(s) .

Instead, the focus should be on how the pedagogical imaginary can create spaces for unexpected results through its iterative unpacking of youth knowledge(s) and practice(s) as resources and movement in learning to teach within field classrooms. In this stance, ideas, theories and practice(s) of each individual become repertoires make these broader, systematic changes possible. Tippins, Hammond, and Hutchinson (2006) discuss an important intersection how histories may come into contact between the culture of classrooms/schooling, the culture of teachers and the cultures of the youth themselves. These authors discuss how international teachers, who came to the United States, negotiated and hybridized their identities within a pedagogical imaginary-- what they call "a transitional space between the purity of their native educational conventions and that of the American schools" (p. 681). Furthermore, these teachers make sense of the historicizing and economical effects of experiences at home as they engage in the expectations of what is science in America. Particularly questioning what "authentic" assessment and experiences in science for are youth--in disciplined-based ways--in their American classrooms. Although this type of pedagogical imaginary is one concerned with the ways teachers from one type of educational culture (home communities) make/remake practice(s) in another educational culture (United States), this study also provides important perspectives for the pedagogical imaginary I seek to understand related to making and re-making practice(s) by generatively hybridizing what they see in these problem-posing, fluid spaces so they become increasingly youth-centered, and equity-oriented in their teacher learning.

In conclusion, taking an *imaginaries as practice* stance in combining social practice theory and pedagogical imaginaries allows to unpack the cultural-historical underpinnings between the institutionalized struggles and views of science teaching as a culture, and the ways PSTs see this in their developing practice(s) in a fluid, problem spaces between methods courses and the field. Particularly, how these interactions allow PSTs to iteratively become increasingly youth-centered and equity-oriented in their practice. Understanding these cultural practice(s) through windows without the pressure of interacting (Sherin & Han, 2004) allows important learning opportunities to better understand how the micro (individual behavior) and macro-social-phenomena (structural behaviors) are important to the uptake and shift towards youth-centered, equity-oriented imagined teaching in science teacher education.

Methodology and Methods

Social Design Experiment

This study is a social design experiment (Gutiérrez, 2008). This methodology combines traditions of design-based research--which aims to engineer particular forms of learning through the systematic study of that learning (Penuel, Fishman, Cheng, & Sabelli, 2011) --with democratizing forms of inquiry that seek to make this type of process a co-construction between different stakeholders (Gutiérrez & Jurow, 2016). Social design experiments work on transforming social institutions and their relations towards achieving equity goals in research, this type of social transformation allows to re-organize systems of activities in which participants become designing of their own futures (Gutiérrez & Jurow, 2016). Taking from Gutiérrez and Jurow (2016)

> The transformational process of becoming a historical actor involves developing a sense of one's own identity in the broad context of time, including how particular cultural practice(s) came into being and how they have enabled and constrained possibilities for learning, and how these understandings inform future-oriented practice(s). The coordination of past, present, and future-oriented actions and identities sets the conditions for new forms of agency central to realizing possible futures (p. 3).

I am concerned with understanding the ways past, present and future-oriented actions in how PSTs develop pedagogical imaginaries towards youth-centered, equity-oriented teaching practice(s). This not only seeks to understand the history-in-person of PSTs as they make sense of and take up on broader meanings youth knowledge(s) and practice(s) , but also how these socially transform and shift activities in their envisioned imaginaries--during the preservice course, through course assignments and in their field work. This means that during the preservice class, we engaged in reflexive revisions of different conceptions of youth in their field classrooms, the types of cultures that exist in those classrooms and how they created and re-created imagined practice(s) to teach in those classrooms.

Social design experiments include the traditional aim of design experiments to create theoretically grounded and practical educational interventions, that take into account the historical injustices and inequities. These form the development of theories focused on the organization of equitable learning opportunities. Injustices that social design experiments support to organize include structural, systemic, and experienced as unjust by minoritized communities. Design of learning environments (such as this preservice course) and "issues of social justice need to be considered together in order to make central the realities of people's lives because the possibilities of learning and development are deeply situated in unevenly developed historical, spatial, and social circumstances" (Jurow & Shea, 2015, p. 4).

Context of study. This study is situated in a senior (4th year) level preservice science education methods course for elementary and middle school teaching candidates. The teacher education program has multiple sections of the same courses taught by different instructors, each organized into cohorts. The PSTs who participated in this TE 400 course are all part of the same class cohort (class of 2018). These cohorts then take their 4th year methods courses together including science, mathematics, social studies and literacy in preparation for their 5th year internship year. They also do their field teaching requirements in the same field school. For this course, the PSTs were required to complete 20 hours of science methods service learning at Liberty Spanish Immersion School, located in Great Lakes City, Michigan.

Setting of the field classrooms. Liberty Spanish Immersion School is located in Great Lakes City, Michigan. Great Lakes City is an urban area hit hard by economic recessions and subsequent population decline experienced across the state (U.S. Census Bureau, 2013).

For the 20 hours of field experiences at Liberty Spanish Immersion School, PSTs are placed to do observations, and assisting with the teaching of science lessons. For PSTs in the course, it was expected that they connect/reflect on what they explored in the class, including readings with what they see in the field classrooms. Liberty Spanish Immersion School is a K-6 magnet school focused on Spanish immersion and global studies. In their school website they state:

> [Liberty's] language immersion model has youth learning Spanish through a variety of formats and content areas. In the [Liberty] community, classmates learn from one another and differences are viewed as strengths. This results not only in a deeper understanding of language but a broader acceptance of varied cultural beliefs. The goal is to produce bilingual global citizens who can learn and share ideas in English and Spanish" ([Great Lakes City] Public Schools, 2018).

According to MI School Data (2018), Liberty Spanish Immersion school had a total enrollment of 270 youth. The study body is made up of 5 ethnicities. Indian/Native American (2.2%), Asian (2.6%), Hispanic (15.2%), Black (48.9%) and White (31.9%). Hence, a lot of the work in connecting between the field and the methods course was around understanding how their teaching can support the Spanish Immersion culture at Liberty.

Teaching science to diverse learners course (TE 400). The course, TE 400: Teaching Science to Diverse Learners, met on Mondays from 9-noon (3 hours per week) during the Fall semester between August-December 2017 at MRU. The course was primarily taught by a white, female urban science education scholar, Dr. C. She has over 20 years of experience researching science and engineering teaching & learning in-school/out-of-school learning environments in various states including New York, Texas, and Michigan, USA. The strengths she brought to the course from her research and teaching in communities were leveraged extensively in designing the course.

TE 400 is a recurring science methods course taught by multiple professors each semester to elementary/middle school teacher candidates at MRU. This iteration of the course was different from other sections, given its explicit focus on equity. Dr. C was interested in re-imagining the ways PSTs might engage with youth-centered, equity-oriented, critical and consequential ways. This course took from multiple conceptualizations and ideas grounded in the literature about teaching science to diverse learners including: supporting funds of knowledge(s) and repertoires of practice(s) in science learning (Nazar et al., 2017), community-engaged and service learning (Calabrese Barton, 2001) and teacher learning from informal learning experiences (Birmingham, 2013).

According to the syllabus, the purpose of the course is to acquaint elementary teachers with various instructional principles and practice(s) for engaging children in science in ways that help them develop abilities to explore the world. Most often, the way that science is taught in classrooms and represented in society more broadly tends to alienate or marginalize many youth beginning from elementary school. Hence, the course philosophy centers on understanding science as a culture. Youth whose primary culture/home culture are similar to the culture of science can cross borders with relative ease. However, those youth whose home cultures do not represent the ways science has been traditionally taught (culture of power) may have more difficulties succeeding in the culture of power that exists in science teaching and learning. The main goal was to support PSTs in recognizing how their view of youth' knowledge(s) and practice(s) and science learning through unpacking ways home/families/communities can become important bridges to the culture of power of science.

Course segments and assignments. Table 4.1 discusses the major themes discussed in the course and how these course themes were pulled together to support a generative understanding of youth knowledge(s) and practice(s) with the goals of supporting pedagogical imaginaries towards youth-centered, equity-oriented teaching practice(s). For the purposes of this paper, I divide up the 13-week course into thematic segments. Cutting across each of the four segments was an explicit focus on four equity-oriented themes:

- Access to quality science education is a civil right & opportunities to learn science need to be afforded regardless of race/class
- Science teaching and learning are cultural processes, which are shaped by history and power. The culture of science/science education can be centralizing or marginalizing to youth because of their race, class, gender, sexuality and other cultural positionings in the world.
- Power dynamics within the classroom can support or hinder opportunities to learn science in meaningful ways. Students and teachers are always contributors to power dynamics in both active and passive ways.
- The outcomes of science learning extend beyond knowledge(s) and practice(s) to include agency, identity, and meaningful action taking in youth lives and communities.

Table 4.1:
Course Segments, Weeks and Topics discussed in TE 400

Segment	Weeks	Topic	How the Topic was Bridged in TE 400	Connections to Field Experiences
1	1	Who are we?	The course began by interrogating who PSTs are culturally, their experiences as science learners (K-16) and developing views of science teaching.	Initial research on field community and Liberty Spanish Immersion School.
2	2-4	Science for all and how do we connect science to the community?	Interrogating what is science, how is science reproduced as a culture, and how to meaningfully connect the culture of science to youth lives. Finally, in this segment, PSTs completed a community lesson plan (in groups of 2-3) to work with youth at Liberty Spanish Immersion School.	Opportunities to unpack culture of science classroom communities.
3	5-10	Focus on Students: How do we teach from youth' strengths?	The focus was on funds of knowledge(s) and recognizing community knowledge(s) and practice(s)? How can PSTs teaching uptake youths' views of science in culturally sustaining ways? Included visits from youth in community, unpacking co-authored cases of meaningful science learning, and unpacking youth' views of science learning in the field.	Opportunities to unpack ways youth in classroom communities participated in science classrooms and practice(s) they engaged in that supported learning.
4	11-13	Focus on Teaching: Structuring Teaching Practices towards Equity	Development of science lesson sequence(s) that incorporated youth funds of knowledge(s) in equitable and meaningful ways. PSTs had opportunities to shape and re-shape lessons as they critically investigated learning from field communities. There was a focus on the Next Generation Science Standards (NGSS Lead States, 2013) in this segment of the course.	Created lesson plans that took learning from youth knowledge(s) and practice(s) in the field and connected it to science topics they taught as final experience in the course.

Segment one focused on the goals and purposes of science. Here PSTs made sense of their own high and low moments in science learning as they experienced them in their own K-12 science education and then created goals for future science teaching. The PSTs were asked to go to Liberty Spanish Immersion School to see their placement and neighborhood to better understand the spaces where youth play at school and in the local community.

The second segment of the course focused on the culture of science. Preservice teachers unpacked how science is reproduced as a culture, and the connections between science and student's lives/experiences in support of a community-view of science in schools. Readings for this segment included notions toward more equitable learning in science from Bang (2016); science education as a civil right as conceptualized by Tate (2001); youth authored cases of consequential learning (Birmingham, 2016); community-based engineering (Dalvi & Wendell, 2015) and culture matters in science education (Pang, Lafferty, Pang, Griswold, & Osser, 2014).

In the third segment of the course, and now that PSTs had time working in their mentor teacher classrooms during weeks 5-10, the focus was on efforts in science teaching based on student's strengths. In this course segment, PSTs were now interrogating culture through a lens of power and culture - recognizing youth as experts in the knowledge(s) and practice(s) they brought to their science learning. This segment was titled: *Youth as Teacher Educators*.

Finally, the fourth segment took the learning in previous weeks to support a development of a science teaching lesson plan sequence that successfully incorporates youth through multiple forms of mediated and re-mediated practice(s) through their generative pedagogical imaginaries of youth-centered, equity-oriented teaching practice(s).

The major assignment of the class was a generative compilation that focused on how PSTs could learn to recognize youth knowledge(s) and practice(s) related to science learning in their classroom communities through the *Cases of Classroom Communities*. These cases aimed at creating conceptual spaces through their pedagogical imaginaries, where PSTs sought to constantly disrupt work, rules, subjects and puts limits on tools in schooling (Dominguez, 2015).

In creating these generative cases throughout the course, the PSTs had the opportunity to "see" something that is yet to be developed or realized, and it is where PSTs considered untested possibilities between theory and practice(s) in their imaginary (Dominguez, 2015). The imaginary was further mediated by artifacts (collected through the methods course to better understand youth and the field) in a fluid, problem-posing space invoking social imagination in support of confronting tensions to constantly linking/relinking and revising professional visions in their practice(s).

Table 4.2:
Course Assignments, Goals and Connections to Broader Pedagogical Issues

Major Course Assignment and Course Segment	Goal of Assignment	Ways Youth-Centered, Equity-Oriented Views Contributed to Goal of Assignment	How Assignments Contributed in supporting Pedagogical Imaginaries in the Field
Science Autobiography, Segment 1	What is science and what it means to PSTs K-16 science experiences.	Unpacking personal science learning experiences through a critical view of culture of power	Viewing science as a culture and that classroom cultures can reproduce systemic inequities in science teaching and learning
Classroom Communities Part 1: Getting to Know Placement Site, Segment 3	Unpacking culture at Liberty including classroom culture, local resources, neighborhood, school and classroom interactions	Unpacking social and culture interactions between Great Lakes City and Liberty Spanish Immersion School	PSTs were supported in critically examining culture of science in the classroom, teaching practices, and modes of participation of students.
Classroom Communities: Part 2: Getting to Know my Students, Segment 3	Build relationships with one youth in their classrooms who they seek to understand better in how funds of knowledge (s) and practice(s) are upheld in science learning experiences	Seeing contrasts between one individual youth's engagement with science learning in comparison to his positioning in the broader class culture	Connecting micro and macro interactions between individuals and the broader classroom culture
Classroom Communities Part 3 & 4: Science Talk, Set-up and Analysis, Segment 4	Create an opportunity to develop a science discussion around a topic of interest of the youth and analyze how PSTs implicated themselves in the productive/or not development of that discussion	Connecting youth knowledge(s) and practice (s) to goals of science teaching through NGSS and building instructional sequences in support of youth views of science learning through the content at hand	Meaningfully connecting science content and practices to how PSTs develop talk moves that uphold knowledge(s) and practice(s)
Classroom Communities Part 5: Lesson Plan and Reflection, Segment 4	PSTs planning a lesson and teaching a lesson. This could be individually or in groups	Lesson plans must include critical views of taking up on youth knowledge(s) and practice(s) in meaningful ways	This lesson provides an opportunity to enact/practice pedagogical imaginaries in practice

Positionality and role in this study. My role in this course was as a co-instructor and also as a critical ethnographer. As a co-instructor I was part of the classroom culture of the preservice course providing Dr. C with support in planning, implementing and reflecting on the work done by PSTs throughout the course. Every Monday after our course meetings, we met for 1-2 hours with Dr. C's course co-designer. There, we discussed important ideas related to how teachers made sense of the course and how they were centering youth knowledge(s) and practice(s) throughout. I took notes during these meetings which served as part of the data of this paper. I was also the liaison for the TE 400 course in the general instructors' meeting for elementary science methods at MRU. Here I also reported to our elementary methods course leader on the happenings and learning from the course.

Recruitment and study participants. The preservice teacher course was composed of n=22 PSTs, where 90% (n=20) of the candidates self-described as white /Caucasian, 5% (n=1) self-described as Black and 5% (n=1) self-described as Asian American/Pacific-Islander. All the PSTs in this study were placed at Liberty in various K-6 grade classrooms. In some instances, several teacher candidates were placed to do their observations in the field classroom. All participants were female.

For this study, a total of 17 students consented to participate in the study. My co-instructor role in TE 400 did not allow me to gather data from the course in-the-moment. Rather, I waited until the spring 2018 semester and visited the PSTs in their mathematics methods course. Dr. H, the course instructor, allowed me ten minutes after his first methods class to discuss the research I was intending on completing. I then asked PSTs to choose their pseudonym, and consent to analyze course data in addition to seeking interviews for their post-TE 400 reflection.

Table 4.3 includes demographic information on the teacher participants. Two PSTs Bella and Carla consented to be interviewed but did not fill out a demographic form due to time.

Table 4.3:
General Demographic Information of PSTs Study Participants

Pseudonym	Age	Race	Major	Teachable Minor	Affiliation with other College of Education Programs	Field Work Class and Grade	Goal of Grade and Location when Teaching/Certified
Kelly	21	white/ Caucasian	Elementary Education	TESOL & English Language Arts	Kappa Delta Pi[8]; Global Educators Cohort [9]	5th grade Spanish immersion	1st grade urban district
Lucia	22	white/ Caucasian	Elementary Education	TESOL	N/A	5th grade non-immersion	Any grade in Southeast Michigan
Sophia	22	white/ Caucasian	Elementary Education	English Language Arts	Kappa Delta Pi; Global Educators Cohort	6th grade non-immersion	2nd grade wherever a job is available
Ciara	21	white/ Caucasian	Elementary Education	English Language Arts TESOL	Urban Educators Program[10]	5th grade immersion	5th grade, urban in New York City
Lena	22	Black	Elementary Education	English Language Arts	N/A	5th grade immersion, Chicago	5th grade urban in Chicago, New York, or Massachusetts
Lucy	21	white/ Caucasian	Elementary Education	Social Studies	Global Educators Cohort	4th grade immersion	Upper elementary in Ohio

[8] Kappa Delta Pi (KDP), International Honor Society in Education, was founded in 1911 to foster excellence in education and promote fellowship among those dedicated to teaching (KDP, 2018)

[9] According to MRU, the GECP "The Global Educators Cohort Program (GECP) gives future educators the tools they need to teach with a global view and to make an impact in today's classrooms, which are increasingly culturally diverse. Through social and educational experiences, MSU's Global Educators are prepared to help young people think about themselves as citizens and stewards of the world around them." (Midwestern Research University, 2018)

[10] Urban Educators Cohort Program at MRU focuses on specialized programs with an urban focus where they learn to appreciate sociocultural issues, understand structures of power, privilege and poverty, embrace cross-cultural differences, create inclusive learning environments and connect with families and communities (Midwestern Research University, 2018)

Table 4.3 (cont'd)

Pseudonym	Age	Race	Major	Teachable Minor	Affiliation with other College of Education Programs	Field Work Class and Grade	Goal of Grade and Location when Teaching/Certified
Ali	22	white/ Caucasian	Elementary Education	Language Arts	N/A	5th grade non-immersion	3rd grade, Nashville, TN
Mary	21	white/ Caucasian	Elementary Education	Social Studies	Kappa Delta Pi, Student Michigan Education Association (SMEA)	6th grade immersion	3rd grade, Michigan Upper Peninsula
Denise	23	white/ Caucasian	Elementary Education	N/A	Honor Society	6th grade non-immersion	1-2nd grade anywhere in Michigan
Alyssa	21	white/ Caucasian	Elementary Education	Language Arts/TESOL	SMEA	Kindergarten Immersion	3rd grade Southeast Michigan
Mariam	21	Asian American/ Pacific Islander	Elementary Education	TESOL	Global Educators Cohort	Kindergarten Immersion	Kindergarten, Detroit
Angela	21	white/ Caucasian	Elementary Education	ZS Endorsement (Early-childhood special education)	N/A	Kindergarten Spanish immersion	Kindergarten in Southeast Michigan Suburbs
Sarah	22	white/ Caucasian	Elementary Education	N/A	N/A	5th grade non-immersion	5th grade-Michigan
Carol	21	white/ Caucasian	Elementary Education	N/A	N/A	6th grade non-immersion	Kindergarten grade-Tennessee
Maria	21	white/ Caucasian	Elementary Education	TESOL	Senior class president; SMEA	6th grade non-immersion	K-5 Spanish Immersion

*missing from the list are Bella and Carla who chose not to fill out the demographic information form

Data Generation

Data for this course was generated from class teaching artifacts (e.g. PowerPoint, syllabus, assignment goals and objectives, class discussions) field notes (of course meetings and of observations from teaching observations at Liberty Spanish Immersion School), preservice teacher assignments, student-authored artifacts that PSTs used as artifacts to develop their teaching, and final course interviews.

Participant observation and weekly planning de-briefs (August 2017-December 2017). I conducted participant observations during the TE 400 course (3 hours per week); and during pre-planning and reflection (2 hours per week), These included over 39 hours of class observation data and 26 hours of data from pre-planning and reflection meetings. These data allowed me to understand interactions and nuanced discussions that take place during the course with specific PSTs, while also allowing me to interrogate overlooked findings in audio recordings or interviews (Spradley, 1980).

Audio recordings (August 2017-December 2017). 39 hours of audio data from the course to review and triangulate the sources with my field notes and artifact collection. These included discussions about class assignments (e.g. Cases of Classroom Communities), as well as responses to PowerPoints or artifacts used as instructional tools in the course.

Teacher talks about field experiences (August 2017-December 2017). During field observations, I spoke with 5 PSTs to discuss what they learned from implementing their designed lesson plans. These teacher talks were not structured but provided with some insight into problems of practice(s) during field work. Some of these discussions allowed for nuanced conversations about support from field teachers and how they view youth taking up on practice(s) during their instructional experiences in the field classrooms at Liberty.

Artifact collection (August 2017-December 2017). I took photographs in the methods course and in the field, collected in-class produced artifacts, activities related to uptake of youth cases, class PowerPoint presentations, and major course assignments.

Final interviews (January 2018-April 2018). I conducted interviews with eleven PSTs in the course from the seventeen that consented to have their classroom assignments analyzed. From Table 4.3, those that participated in final artifact interviews included: Lena, Alyssa, Sarah, Denise, Angela, Ciara, Mariam, Mary, Carol, Maria and Sophia.

Data Analysis

In this section, I describe three interacting phases of data analysis: (a) transcribing interviews/classroom recordings (b) pattern finding, triangulation and data reduction strategies and (c) connections to broader framework of imaginaries as practice.

In the first step of data analysis, I transcribed all final artifact interviews for the eleven teachers who interviewed in Spring 2018. As data were transcribed, I began to notice initial themes and patterns in and across participant talk regarding three important themes. The first was tied to changes in comfortability with teaching science before and after the course, the second was how views of classroom communities related to emerging views of equity in support of youth' funds of knowledge(s), home/community knowledge(s) and third was related to initial views of imagined practice(s) to support youth they saw in their classroom communities. Throughout this process, I wrote analytic memos connecting themes, patterns and questions that allowed me to think more deeply about these aforementioned points. I then used the analytic memos to build a stronger coding scheme in the data analysis for triangulating my data with other artifacts in the course.

The second stage of coding then took these broader themes in the first pass (e.g. comfortability in science teaching, views of classroom communities, views of youth, emerging equity views) and mapped these onto the class assignments and artifacts produced by the participating seventeen teachers. Through constant comparative analysis (Glaser & Strauss, 1967) and data reduction strategies (Miles & Huberman, 1994) I developed codes through layering views of PSTs in their final interviews, with experiences throughout the course as seen through their assignments and class artifacts. These included: layering of K-16 science experiences with science teaching, examining youth in the classroom, in the context of teacher learning cases/ in the community, culture of power in science and opening borders, cultural knowledge(s) as assets in science learning, recognizing funds of knowledge(s) and repertoires of practice, resource views of equity, teacher practice(s) views of equity, connections between youth in the classrooms, connections between teachers in the classroom (mentor and mentee), connections between mentee and youth in the classroom.

Finally, I used my course field notes, and teacher talks to triangulate data using the framework of imaginaries as practice(s) . Through this frame, I then took all the codes from the second coding pass and organized them into how PSTs imagined practice(s) throughout the course in ways that first, took up on their own knowledge(s) and practice(s) (and where in the course and how it happened) and second how this translated to their emerging views of teaching in youth-centered, equity-oriented ways.

Finally, two major themes emerged from the data which will be discussed in the findings section.

Findings

In this section, I introduce two major findings of this study. In the first finding, I found that having opportunities to layer and examine knowledge(s) and practice(s) in PSTs science autobiography (e.g. reflecting on previous K-16 science experiences and current science stories) alongside examining experiences with youth a) in the classroom, b) in community contexts and c) through cases, provided PSTs opportunities to critically re-read and re-think their purposes and goals for science teaching.

In the second claim, I discuss that opportunities for PSTs to make sense of youth's knowledge(s) and practice(s) in assets-based ways that centered community, home, and classroom resources and movement of these repertoires became the basis for naming new youth-centered equity-oriented practice(s).

Having Opportunities to Layer and Examine Knowledge(s) and Practice(s) Through Previous K-16 Science Experiences and Current Science Stories Alongside Examining Experiences with Youth in a) the TE 400 Classroom, b) Community Contexts (Including the Field) and c) Youth-Authored Cases Provided Teachers Opportunities to Critically Re-Read and Re-Think their Purposes and Goals for Science Teaching

In unpacking this first claim, I make three main points: Iterative understanding of personal experiences in K-16 science education for PSTs in tandem (experiences and then identities) with those of youth (experiences they see in the classroom with way youth discuss meaningful science learning experiences) supported PSTs in becoming more critically aware of a) teaching practice(s), b) relationships with youth and c) resource availability (including funds of knowledge(s) as resources) in promoting more equity-oriented science education.

Iterative unpacking of K-16 experiences through imagining teaching practices. In the beginning of the course, PSTs were prompted to ponder about connections between their science learning experiences and ways they felt these experiences were meaningful to them. The goal of this activity was for PSTs to understand how the culture of power in science functions in their own lives. In this work, PSTs detailed experiences of their own K-16 science learning and examining these experiences alongside hopes and fears of their future science teaching. They then connected these hopes and fears to the ways they saw science teaching in their field classrooms and with the student learning cases they examined throughout TE 400. These connections led to PSTs developing pedagogical imaginaries where they wanted to provide greater and more meaningful connections between science learning and the lives of their youth in the field (and future youth they hoped to teach).

Teaching practices in the TE 400 classroom. In critically connecting PSTs science learning experiences and positioning youth as experts in the science methods course, the PSTs were prompted to unpack views of their own science learning experiences. High moments in this critical unpacking included references to "fun" science learning experiences that connected community and out-of-school spaces. "Low" moments were related to ways hard science courses in high school such as chemistry, biology and physics were impersonal and not connected to the ways PSTs viewed their own purposes and goals of science learning (Field Notes) In addition, most PSTs discussed how across their science education, the teaching methods and practice(s) of their science teachers played a critical role in how they viewed themselves as meaningfully connected to and learning from their science education experiences. Ali in her science reflection map discussed:

> I have realized that my science experiences are greatly influenced by the teachers that I have had. One of my low points was a direct reflection of my teacher…he had a bit of a condescending tone which was very difficult in a class [where I had difficulty]. It was a dry class with little hands on experience and the teacher's attitude discouraged me from getting help and asking questions (Science Map, Segment 1, Ali)

In this example, Ali reflects on how her science teacher created a culture with limited opportunities for youth to ask questions. Compounding this culture with his teaching practice(s) in the classroom while presenting science content (e.g. condescending tone, dry teaching of the class, limited hands-on experiences) discouraged Ali from engaging meaningfully in her science learning experiences. For Ali, these science learning experiences turned her into "[shutting down] and get[tting] frustrated when [I] do not understand something and reading straight from science books was often difficult to comprehend" (Hopes and Fears, Segment 1, Ali).

These K-16 experiences shaped Ali's pedagogical imaginaries for teaching science. Ali discussed: "I am hopeful that by the end of the [TE 400] semester, I'll have an overall better understanding of science. I hope I will be more comfortable in teaching the classroom setting after a semester in my field placement. I hope to gain confidence in my science skills" (Hopes and Fears, Segment 1, Ali). Important in Ali's imaginaries here is that she wants to better understand science content (particularly because she felt her science education did not support her in developing this content knowledge(s) in her learning experiences) so that she becomes more comfortable in her elementary teaching. In addition, she wants to learn about science teaching through her field experiences so that these together support her in gaining greater confidence in her science teaching skills.

In another example related to how the TE400 course supported to unpack K-16 science learning towards imagining teaching practice(s), Carla discussed how she experienced a science education was engaging, relatable and enjoyable for her learning. Particularly, Carla mentioned how her experiences out-of-school were recognized in school by her teachers. These experiences included visiting museums or local parks (Science Map, Segment 1, Carla). Because of these experiences, Carla's imaginaries regarding her science teaching were connected to her experiences in science learning: "A meaningful science education is going to be a high priority for my classroom…connecting with youth…as individuals. This means I have to get to know them, where they come from, their community, their interests, more than just who they are as a student, but their identity outside of school as well" (Hopes and Fears, Segment 1, Carla). Carla's imaginaries about her future teaching practice(s) related to her science experiences connect not only her view of how science education must be meaningful, but also connecting to youth as individuals, where they come from, who they are, their communities, their interests and their all-encompassing identities that they bring into their classroom learning.

***Teaching practices in community (field) contexts*.** PSTs also critically unpacked and examined their K-16 experiences alongside their field experiences. More importantly, their field experiences at Liberty created more expansive views of the culture of power inherent in their educational experiences, and these too became important in imaging teaching practice(s) in youth-centered, equity-oriented ways. Ciara in her final interview noted connections to the ways power and privilege were part of her science education. She then connects these experiences to pedagogical imaginaries in ways that would uphold youth knowledge(s) and practice(s) in her science teaching.

> I went to school in a pretty affluent area, but I knew from the get-go I wanted to get an educational career in an urban setting. I had witnessed youth come into my district from a failing low income district nearby and worked one-on-one with them, especially in science class, and that opened my eyes to how different learning is…districts even if they are near each other…are different. I grew up in a pretty white-washed education system and this has impacted the ways I want to teach my students. I wish that I had teachers that broke the norms, but that wasn't the case. I want them to feel welcomed in my science class, become more informed citizens and help the world with science (Final Interview, Ciara).

In this excerpt, Ciara connected her science learning experiences to issues of power and privilege in her community. First, she unpacked how she saw differences in educational opportunities for youth who were in districts that were geographically near each other but provided varying educational experiences for their youth. Particularly by referencing how youth from a nearby low-income failing district, who moved to her more affluent district, were now positioned to learn science from the youth in her class. This experience positioned Ciara as viewing herself as a science expert however she became critical of why she had this expertise and other youth did not (Final Artifact Interview, Ciara).

Her educational experiences growing up as a white, affluent female in a "white-washed" school district prompted her to criticize and critically re-examine the ways she could imagine changing the practice(s) for those youth in her science class. By recognizing the culture of power that is reproduced educationally, she imagined breaking the norms in her future classroom challenging how these same norms were not broken in her science class for her peers from the neighboring district. This imaginary is a direct challenge to the "white-washed" teaching she experienced so that her future youth feel welcomed in their science class and become informed science learners/critical users of science.

The critical uptake of how youth can and should be welcomed in their science class, but also positioned as experts was seen again in Ciara's unpacking of the practice(s)he viewed in her field classroom at Liberty. In her Classroom Communities assignment, Ciara discussed that her field classrooms' science instruction was "ongoing, rather than individualized lessons." This meant that topics were connected by broader, big ideas rather than individual lessons on different topics. Because of how the lessons were connected, this prompted Ciara's mentor teacher to use anchors to support the purposeful bridging of science ideas over time in the Spanish Immersion classroom. Ciara noted that in the classroom community, Ms. Hufflepuff used large youth created think-alouds, pictures, and writing to showcase youth learning and connections to broader science topics in the classroom. Teaching practice(s) of revoicing terms and student responses, as well as using sound effects, connected science terms to their learning experiences (Getting to Know the Field, Classroom Communities Assignment, Ciara).

Ciara also noted that in Ms. Hufflepuff's classroom, Spanish immersion was favored over uptake of science content, which limited Ciara's views of developing imaginaries specifically around science learning (Field Interview, Ciara). However, Ciara did see how Ms. Hufflepuff engaged in inclusive teaching practice(s) that made youth of other cultures feel welcomed in her Spanish immersion class. Ciara noted:

> [the classroom teacher, Ms. Hufflepuff] definitely gives [the youth] the opportunity to discuss their experiences' A lot of her lessons are very open to discussion, and the youth don't even really have to raise their hands. They can just blurt out their answers, and there are some [00:03:00] youth who are native Spanish speakers... One student in particular is

from Mexico. I interviewed him for [classroom communities' assignment], and she relies on him and a few others that speak Spanish fluently for help with some Spanish words she might forget when she's speaking in Spanish or conjugating verbs that she can't remember. Things of that nature…I will use this observation to help me with supporting youth in my science class" (Final Artifact Interview, Ciara, p. 3).

In this example, Ciara discussed how her mentor teacher provided varying entry points for her youth into Spanish immersion. Particularly, Ms. Hufflepuff valued the expertise of youth in her class who were Spanish speakers. By doing so, she was able to provide meaningful connections to those youth, and also legitimized their knowledge(s) and practice(s) so that others, including the teacher, could learn from them. This experience helped Ciara develop imaginaries that focused on youth repertories and the knowledge(s) and practice(s) that youth already have. Here, Ciara states "I will use this observation to help me with supporting kids in my science class because I see there's value in recognizing kids who know the language to help others learn the language too" (Teacher Talk, Ciara). This field experience helped Ciara critically examine and imagine how knowledge(s) and practice(s) of youth were upheld and recognized by Ms. Hufflepuff and how she could use that in her future science teaching practice(s).

Teaching practices in youth cases. In another portion of the course, PSTs were supported in unpacking cases of meaningful science learning of youth in Great Lakes City. The youth: AD, Faith and Christopher were invited by Dr. C to co-teach the TE 400 course focused on *Youth as Teacher Educators*. The goal of including the cases and the youth as co-teacher educators in TE 400 was to support PSTs in critically unpacking ways that AD, Faith and Christopher merged home/community knowledge(s) and practice(s) with their science learning to create engineering design projects that solve community problems. In addition, by having the youth present, and positioning them as experts in their science learning experiences in TE 400, helped PSTs to discuss with them views of their science learning and teaching alongside perspectives of youth in the cases and in-the-moment. Working with the cases supported PSTs to examine and imagine better ways to support the youth showcased in the cases and how these would transfer to supporting the youth in their teaching practice(s). The analysis of the cases is in chapter three of the dissertation.

Faith, who created a solar-panel fan hat worked with Ali and Sophia on her FANcy hat design case. In unpacking the case, Ali noticed how Faith worked in the after-school program since she was 12 years old and that she was "big on using her imagination… along with being silly and thinking of other problems to come up with her invention" (Faith's Case, Ali and Sophia). The PSTs noted that Faith wanted "to show people how she could create things using her mind and educate others about her learning through the FANcy hat design" They concluded that the goal of the hat was to "keep cool while looking cool" and that "she thought of her family, friends and community when creating the hat because she wanted to [create] something that can benefit those close to her was important to her" (Faith's Case, Ali and Sophia).

Through the experience unpacking Faith's case, Ali and Sophia discussed three important imaginaries that they would take into their future teaching. The first imaginary was that "youth like Faith have beliefs about how they see themselves and their learning and can very well portrayed using imagination and creativity." In this, Ali and Sophia noted that it is important to uphold the ways youth see themselves in their learning and recognize those views as legitimate in their classrooms. Particularly, Faith, Ali and Sophia together discussed how her imagination and creativity is what led her to create her FANcy hat, but that she was only able to show people about it when she developed her case (Field Notes). The second imaginary that Ali and Sophia developed was:

> By looking at how Faith describes herself and her invention, it can be very beneficial as a teacher to help understand how her mind works and how she may learn best. Faith stresses her use of her imagination in the creation of her invention. As a teacher, you can bring in the use of imagination to other lessons to help Faith put forth her best work (Faith's Case, Ali and Sophia).

To Ali and Sophia, this imaginary was connected to unpacking how Faith's "mind works" and bringing "her use of imagination to other lessons to help Faith put forth her best work" (Faith's Case, Ali and Sophia). Sophia and Ali further noted that by incorporating Faith's use of imagination and habits of mind, "this can help create lesson plans that relate to what is important to the youth and what they are exposed to at home" Furthermore, by "recognizing, as teachers, that youth are challenging our perspectives when they begin to think outside of the box and use their own background, knowledge(s) and experiences, we see that their own conclusions don't correlate with conclusions drawn up in our [teaching] head" (Sophia and Ali, Home, My Engineering Cycle and my Invention, Faith Case, Segment 3).

This imaginary is important because it not only recognizes that Faith's imagination is important in her learning, and that teachers need to create lesson plans and activities that uphold these imaginaries, but also that they recognize that youths' views of science learning help teachers to move away from a science teaching that only they feel is meaningful to their youth. Rather in recognizing youth's backgrounds, knowledge(s) and experiences, teachers could be challenged to teach outside the box.

In a third imaginary, and building generatively from the second, Sophia and Ali noticed that youth have their own views of science that is meaningful and important, but that teachers are not taught to recognize them. By seeing youth do science that matters in their community and that this science is meaningful to the youth, PSTs feel more comfortable in developing imaginaries to support a type of science learning that matters.

Sophia discusses this imaginary in the following transcript:

> **Christina:** You talked about Faith's case, how did that support you [00:22:30] and seeing work around [knowledge(s) and practice(s)].
>
> **Sophia:** I liked seeing that because ... it was the first time I had ever seen science being used as something that could help kids [science that matters]. Or, kids being told that they can do something to fix the problem that's in their community or being told that they can ...Every time that I always thought that there was something I could do to help my community, or anything, it was always some big extravagant thing. But I didn't feel like I [00:23:00] had the means to do when I was that age. So, it was cool that they had the means to fix a problem that they thought that was in their community (Final Artifact Interview, Sophia).

The results from Ali and Sophia's work with Faith her fancy hat shows how critical it is for PSTs to *see* that youth can do science in meaningful ways. By supporting PSTs in developing imaginaries around science that matters in and within their K-16 experiences, these can provide opportunities to bridge home, family, community knowledge(s) and practice(s) with their science learning.

Iterative unpacking of K-16 experiences through imagining relationships with students. Important to the TE 400 course was how PSTs generatively began to see emerging relationships with youth as an important part of imagining practice(s) in support of those youth. Throughout the course, in the field, and learning from the youth cases prompted PSTs to unpack important dynamics between how their teaching could/would/should impact their youth in the field and also those they hoped to teach.

Imagining relationships with students in the TE 400 classroom. In order to support emerging views of identity in the relationships PSTs can have with their youth, Dr. C began class on September 11, 2018 asking PSTs to detail "critical aspects of their identity" (What is Science for All, PowerPoint, September 11 Class). In this discussion, PSTs connected their societal roles with personal views of ethnicity and culture. During class discussion, PSTs discussed how their identities shaped the relationships they valued at home, in school and in their communities. For one PST, having a sibling who had the same teacher in science years, and knew how family and community interests were important to her sibling, helped her to build a better relationship with her science teacher once she was as student in her classroom. Using this as an anchor, Dr. C then prompted PSTs to connect these emerging views of identity ways youth identify themselves in their science learning (Field Notes, September 11, 2018, Segment 2).

In doing this, Dr. C had PSTs read a piece by Birmingham et al. (2017) which detailed how four girls in Great Lakes City co-created cases of out-of-school science learning through a lens of science that matters and their connections to identity. Preservice teachers read and analyzed the cases of the youth (Maya, Nicole, Caitlyn, and Hannah) and then created emerging views of identity in these cases for the youth in the study. Table 4.4 is a summary of the connections and examples the teachers made regarding science that matters for the four girls in the paper.

Table 4.4:
Preservice Teachers Connecting Pedagogical Imaginaries to Youth Identity and Science that Matters (Science & Community, September 18, 2018, Field Notes, Segment 2)

Youth in the Birmingham et al. (2017) piece	PST (s) connections to identity and science from the youth stories in the piece	PSTs developing imaginaries based on views of identity and science from the youth stories in the piece
Caitlyn	Youth connected economic issues with electricity bills and light bulbs used at school (e.g. new light bulbs for school) Using new light bulbs at school could help school/community to save money and energy Science knowledge(s) helped community save money	Supporting a science that matters, that is hands on, relevant to them and their community and allows them to make a positive impact in family and community Exploring issues that matter to youth
Hannah	Using a lightbulb to save energy creates accessibility for the community Wanted her course to be "fcience" or science that is fun and that matters	Using science for a positive outcome produces change in communities Science needs to be fun and impactful in the community. Classroom science should be relatable to youth and ways they view community.
Nicole	Employed new energy technology and putting it to action in her community Impacts on environment matters through actions	Using science to positively impact their lives and the surrounding environment Students should bring into science classrooms issues of community, but take learning in science class and apply it to their own lives
Maya	Looked at H20 cycles and how this learning could help her community environment.	Doing science not because you have to, but because you want to make a difference in the world and your community. Teachers need to make science applicable to the real world.

In unpacking the stories of the four youth in this reading, the PSTs connected how their views of identity and a science that matters for youth were connected to the ways teachers could develop relationships to youth and their communities in their science classrooms. In their developing imaginaries related to the unpacking of this piece, PSTs discussed how supporting science that matters are important in science class because it makes science relevant to youth and allows for changes and positive outcomes in communities. In addition, science learning can become fun and impactful to youth so that they could make a difference in their world and their community. In addition, this was the first time that PSTs implicated themselves in their developing imaginaries. In the discussion, they discussed “teachers need to make science applicable to the real world…we need to make it happen” (Science & Community, September 18, 2018, Field Notes).

Imagining relationships in community (field) contexts. One of the ways TE 400 supported developing relationships between PSTs and youth in their field classrooms was across their Cases of Classroom Communities assignment. This assignment prompted PSTs to unpack developing views of youth in their classroom communities and then used this broader classroom culture to analyze how one student participated in that classroom culture. The learning from these youth in the field communities supported PSTs to develop pedagogical imaginaries important in how the relationships with these youth supported their science teacher learning in more youth-centered, equity-oriented ways.

One example related to imagining relationships with youth in the field is Angela’s unpacking of Child A’s (as she called him in her case) family, home language, and interests outside of school. Angela began to work with Child A in her field mentor’s classroom and quickly started to build a relationship with him to understand his out-of-school learning experiences. These experiences Student A shared with Angela included video games, love for wrestling, building toys and playing with his brothers. Angela noted that Child A is a student with disabilities and is also the youngest of his siblings. Because of ability status and his age, his siblings help him extensively at school. Teachers recognize Child A’s needs and allow siblings to check on him between classes (Final Interview, Angela). Given Child A’s needing special instructional supports as mandated by his IEP, Angela noted that the teacher in her field classroom supported Child A with developing leadership roles. Angela noted that these leadership roles were incremental in nature. One day, the teacher would support Child A in talking with other students with his science ideas and in the next observation, she would support him to co-lead class discussions. According to Angela, this helped Child A shape and support positive classroom interactions for himself with his classmates. Being able to see this generative support for Child A helped Angela see how youth knowledge(s) and practice(s) could be generatively and systematically supported by teachers through classroom instruction. Angela added: "positive interactions that are supported in the class for Child A helps him stand up for children who like him, also have disabilities, but do not have the supports in place. By asking them to play with him, he wanted to make sure they didn't feel excluded as well" (Classroom Communities Part 2, Segment 3, Angela).

Angela's emerging imaginaries in building relationships with youth with disabilities is connected to who she is as a teacher. She noted in one of her teacher talks of her field experiences that her mother is a special education teacher in the district that she grew up in (Teacher Talk, Angela). Because Angela grew up seeing her mother teach youth with disabilities, this prompted an interest in her to become a teacher in this same field. In seeing her mom teach, she began developing early imaginaries (even before entering her teacher education program) on the types of classroom spaces she wanted to develop in support of youth with disabilities in mainstream classrooms. Angela was critically aware of how policies in K-12 and limited funding were detrimental to supporting youth with disabilities with an equitable education (and science education) (Field Notes). In her future classroom imaginaries, she noted that she wanted to create spaces that were open and non-restrictive (open spaces, carpets, stations, not 100% sitting in chairs and tables). Angela noticed from her earlier observations in her mother's classroom that ways youth were positioned to learn in tables and chairs, especially youth with disabilities, created unsafe learning spaces for them. (Final Artifact Interview, Angela). In working with Child A and building a relationship with him, and seeing how her teacher supported him, Angela merged her personal learning experiences with students with disabilities from experiences in her mother's classroom with those of her field experiences. These prompted her to re-imagine ways to support Child A's knowledge(s) and practice(s) in her future teaching.

In another example, Lena in her field classroom learned about the importance of building relationships as a teacher with her youth, particularly regarding recognizing non-verbal communication as a form of engagement in classroom learning. Lena discussed:

> Justin did not offer any examples during [whole group discussion in the lesson]…I did see his eyes jump [with] each student's response, which demonstrated to me his interest with the topic and eagerness to learn more about what was being discussed. The teacher also asked for my insight on [Justin's engagement] and it reminded me that, "...the more you show genuine intellectual and scientific interest...the more you expand the space of possible relations among you, your youth and science. *(Bang, M. et al., 2016)* (Classroom Communities Part 2, Lena, Segment 3).

In this example, Lena's recognition of Justin's engagement in the science discussion prompted her to imagine expanding new ways in which youth like Justin could be recognized in the classroom. Lena's mentor teacher connected Justin's engagement in supporting Lena's learning to teach. By doing so, Lena discussed with her mentor teacher imagined connections between Justin's engagement and the ways TE 400 discussed varying ways youth could show genuine intellectual and scientific interest in science learning. To Lena it is important that her pedagogical imaginaries include expanding relationships and spaces between teachers, youth, and science (Classroom Communities Part 2, Lena, Segment 3).

In another example of Lena connecting with Justin in a later part of the course, she noted:

> After [classroom communities] I wanted to keep working with Justin through developing his math skills. I was able to learn about some of the activities that he does outside of school like basketball. I also learned that he rode the bus home and I was able to use this as an opportunity to mention pollution as it regarded to the science lesson from earlier in the day. I made the connection that if more youth would catch the bus like him, it would reduce pollution of CO2 emissions from cars. We also talked about how walking can reduce pollution as well. Each visit to Liberty offers me the opportunity to learn about each student's learning process, as well as, how I assess my own learning of them. (Final Artifact Interview, Lena).

In this example, Lena discusses how learning about Justin through her student case in the Classroom Communities assignment prompted her to want to continue connecting with him in the remainder of her field experience. Here her imaginaries of supporting Justin were to some extent enacted as she engaged in practice(s) to support meaningful connections between his math learning and science learning. Lena learned about the activities he liked to do outside of school, and connected riding the bus home to learning about CO2 emissions from cars. This knowledge(s) of Justin riding the bus prompted an imaginary of now connecting youth funds of knowledge(s) to ways she could build a lesson around reducing CO2 pollution from car emissions in Great Lakes City for the rest of the class.

By unpacking these experiences, Lena felt greater connections to her field classroom and the community in Great Lakes City and ways that these experiences could shape her view of youth and how they learn in her future teaching. She detailed that the field experiences at Liberty "offer [her] the opportunity to learn about each student's learning process, as well as, how [she] assesses her own learning of her students" (Classroom Communities Part 2, Lena, Segment 3).

Imagining relationships through youth cases. Unpacking youth cases of meaningful science learning also provided opportunities for PSTs to see emerging relationships and imaginaries between themselves and the youth who developed the cases. In this example, Lena and Bella analyzed AD's duct-tape thermometer tie case. In analyzing the case, the PSTs had opportunities to look at AD's authored views about her science learning and speak with AD about what she thought about their sensemaking of her case. As a way to show their learning, the PSTs developed tables that unpacked the themes related to specific learning from the case and discussions they had with the youth about their case. Table 4.5. shows Bella and Lena's Analysis of AD's Poetry Writing related to making her duct-tape tie in her case.

Table 4.5:
Bella and Lena's Analysis of AD's Poetry Writing in her Case

Themes evident in AD's poetry writing?	How do the themes in AD's poetry writing relate to (1) her schooling experiences and (2) out of school experiences?	*How would you support AD and her poetry writing in your classroom?*
Importance of writing in AD's life	She always loved to write, but never knew how important duct-taping and her experiences growing up as a young woman was for her until she was able to write about it in her English class.	Using poetry, or free writes, as a way to express what she knows about subject-matter (e.g. science).
Experience of working with duct-tape	She gets asked by those around her a lot to make things for them, but they don't realize how much effort it takes to make one of the pieces. It is hard based on how to set up the duct-tape, how to place the lines, and how to put it together.	Bringing in her out-of-school experiences and relating them to her in-school experiences as it interests her.
Love and relationships-mostly about relationship with dad	She writes about her life with her dad and the struggles they've been through together. Often struggles from outside of school lead to struggles in school.	Poetry is a way for her to express her emotions and past experiences that shape who she is as a person and as a learner.
Assumptions people make about her	In school, people may make assumptions that she is "funny and real" but she says there's more to her. This relates to how she thinks her peers may feel about her. Her outside of school life can also be affected by this as her experiences at home are important to who she is as a person.	It's important to take note that she may not be her true self in class so, as a teacher, acknowledging that she may be upset or having a rough day may be important in her education and how that helps her throughout the school day.
"The struggle"	The struggle is life -- in school and out of school, it is the experiences that add up to make you who you are.	She explains that she is "selectively social" so it is important to understand that as a teacher she may not always feel comfortable speaking up, but that doesn't mean she isn't thinking. Also making things culturally relevant and relevant to her community is important and will likely make her more interested in the lesson.

In unpacking the themes related to AD's use of poetry in her case, the PSTs noted several connections between poetry writing and AD's life. First the PSTs discuss how AD uses writing as a way to detail her love and relationships with family and community members. She also details the emotions harbored by working and designing with duct-tape. In her poetry writing, AD challenges assumptions made of her and who she is by detailing her struggles as a learner in school/out-of-school.

In discussing important pedagogical imaginaries developed from unpacking AD's case, Bella and Lena discussed how to support a student like AD in their classrooms, they would create spaces for using poetry and free writes as a way to engage youth in the subject, but also as a way to center youth expressing their emotions in safe ways (Field Notes). In addition, as teachers of AD, they would also bring more out of school experiences and related these to topics in school that could interest her. The PSTs also connected their imaginaries to recognizing AD's identity in the class. "[AD] may not be her true self in class, so as a teacher acknowledging her [emotions] could support her [in the classroom]." In addition, by imagining ways to implicate themselves in teaching, they discussed with AD during their analysis how they would shift their future classroom practice(s) in support of youth like AD in culturally-relevant ways. They discussed that by supporting AD's view of herself as selectively social, they would create experiences that can help her to meaningfully engage in science class in individual ways (Field Notes).

The experience of having AD in class was particularly fruitful for Lena in unpacking imagining relationships with youth. The following transcript details Lena's personal experiences in science learning alongside her experience of learning from AD in TE 400.

> **Christina:** In what ways, or do you think it was helpful to have youth come into our methods course?
>
> **Lena:** [inaudible 00:23:03] definitely a great experience because I feel like in high school ... the most I've done is probably in Biology and we dissected a frog and that was

probably the most hands-on opportunity…And with [the youth], they were able to go outside of the box and draw from what they like to do and integrate that with how they think about science and I feel like it was really interesting simply because I wasn't given those opportunities when I came to science.

Christina: Who did you work with?

Lena: AD with the duct-tape

Christina: Okay, [AB 00:24:25]. Did you have any interesting conversations with her that day? Or did you talk about anything?

Lena: Mostly we asked her about college and what she planned on doing with college 'cause there's a scholarship…where you made your prom dress out of duct tape. You could win a large amount of money. We also talked about her trial and error because she initially said [her original idea turned out to be] different. We also talked about why she was doing it and she went into her family's history and I felt like that drive and that motivation, I think that's important in what you do. You want to be able to teach youth that you have certain values and what you value, you work for (Lena, Final Artifact Interview).

Lena's unpacking of her science learning experiences alongside her AD's work with her duct-tape tie showed how important it is again, for PSTs to see and generatively unpack ways that science can be done by youth in meaningful ways for them and their communities. Lena's experience with science in dissecting a frog as their only hands-on experience in science education was similar to the majority of PSTs in TE 400 (Field Notes). However, being able to unpack how youth knowledge(s) and practice(s) could be a critical part of science learning, through critically engaging them in unpacking meaningful science experiences of youth help

PSTs in seeing that youth can "think outside the box." This implicates PSTs to view themselves as important in connecting this critical engagement between youth and science in the classroom.

In this very short connection with AD, Lena understood not only why the tie was important to AD, but what she learned from making the tie, the challenges she had in developing it and how her love for duct-taping was more expansive than just the tie itself. In learning from AD and building this relationship with her, Lena further imagined ways she could motive her future students and value who they are and what resources they bring to their science learning (Teacher Talk, Lena).

Iterative unpacking of K-16 experiences through imagining resource (including funds of knowledge(s) as resources) availability. Throughout the course, PSTs were supported to develop imaginaries that connected resources to the ways they imagined teaching science. Although the PSTs noted that access to resources (e.g. materials) were important to open up borders to science in equity-oriented ways, these views shifted throughout the course as they generatively unpacked views of what counts as resources in TE 400, in their community contexts and through the youth-authored cases. I will unpack the generative transformative view of imagined resources in each of these below.

Imagining resources in TE 400. In TE 400, PSTs were supported in recognizing resources as an important way to connect youth to the culture of science. In beginning to conceptualize this view of resources, PSTs unpacked meanings of equity in science teaching through Tate's (2001) *Science Education as a Civil Right.* In this piece, the author emphasizes how science is socially and historically connected to opportunities in society. Especially in that science education is not provided equitably to all youth, especially minoritized Youth of Color. This unequitable teaching of science education has led to limitations of access to science career choices and ways they can be supported meaningfully in their science education. The author emphasized in this reading that views of equity of science learning should move from access to material resources (such as providing opportunities to engage in science practice(s)) towards one that implicates teachers in providing equitable opportunities in science learning. During the discussion on Tate's piece, PSTs developed conceptions of their views of what it means to teach science equitably. Most PSTs in this discussion connected to their own science learning experiences in regard to how they had limited opportunities to engage in science because their schools lacked access to material resources (Field Notes). In this view of resources, teachers imagined that an equitable science classroom would need access to science resource materials. By unpacking this idea further, they developed posters about their learning from the Tate piece. These were the main findings:

- Opportunities to learn science and access to science need to be afforded regardless of race/class
- Affording equitable opportunities to learn science means access to the culture of science
- Use of materials and resources can support or hinder opportunities to learn science (Field Notes, September 11, 2018, Segment 2)

In these examples, PSTs were initially connecting equity in science 1) to afford opportunities regardless of race and class, 2) meaningfully engaging in science means having access to materials that scientists use. Here their imaginaries around equity involved limitations in access to material resources in science class, and communities who are racially and economically diverse fared worse in having equitable access to these resources because of limited funding in majority-minority school districts (Field Notes).

In order to challenge this “settled” equity view of science strictly on resources, Dr. C worked to systematically support PSTs in unpacking funds of knowledge(s) (Moll et al., 2005) as another type of resource in science learning. Dr. C began by sharing readings associated with learning about funds of knowledge(s) through examples of ways youth merged their knowledge(s) and practice(s) with/in science learning experiences. Overall, PSTs discussed that funds of knowledge(s) are knowledge(s) that youth gain from their everyday lives and that these are built over time through experiences that helps strongly connect what they are learning to the knowledge(s) the youth already have about those topics (Field Notes, Segment 3). Particularly, through analyzing funds of knowledge(s), PSTs understood that the uptake of these as real-world knowledge(s) of everyday family, home, and community practice(s) could support a meaningful science education. Preservice teachers also began to question during the class discussion ways that their relationships with youth could be leveraged to support funds of knowledge(s) in the classroom (Field Notes, Segment 3).

For example, conversations around “establishing relationships with youth [as teachers]” and “help[ing] youth understand each other” (Field Notes, Segment 3). Through this discussion, PSTs were now beginning to connect how individual youth’ funds of knowledge(s) and uptake could be shaped by relationships with teachers and relationships between youth in the classroom (Field Notes, Segment 3). Through uptake of these funds of knowledge(s) as resources, greater opportunities could be forged to promote diversity and challenge negative stereotypes of youth. Figure 4.1 shows examples of imaginaries developed from the funds of knowledge(s) discussion in TE 400 and how these developed into recognizing funds of knowledge(s) as resources for supporting youth-centered, equity-oriented imaginaries.

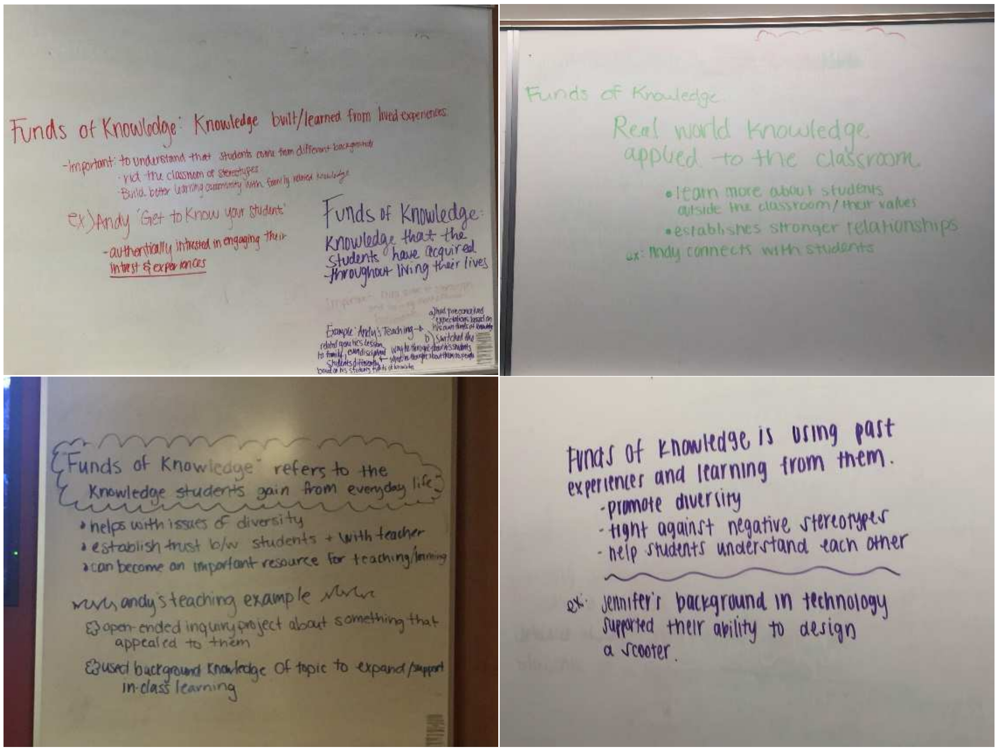

Figure 4.1: PSTs imaginaries about FoK during class discussion.

Imagining resources in community (field contexts). When imagining practice(s) that uphold resources in community and field contexts, Denise and Ciara's example in designing a lesson on lift, weight and thrust was of particular importance (Figure 4.2). They connected the lesson to NGSS engineering performance expectations, grades 3-5:

- **3-5-ETS1-1.** Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- **3-5-ETS1-2.** Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- **3-5-ETS1-3.** Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved (NGSS Lead States, 2013).

In this example, the PSTs planned the activity with an eye towards systematically taking up funds of knowledge(s) as resources in their teaching. During the class discussion in planning for this lesson, Denise and Ciara had conflicting views of what it would mean to uptake funds of knowledge in this lesson (Field Notes). To determine the best course of approach, they went to Dr. C three times during their lesson planning workshop to ask: “how can I know what students know about lift, weight and thrust? can’t we just ask them?” (Field Notes). Because the goal was to engage the youth in practices of engineering design, Dr. C suggested finding an activity that could merge community knowledge and practices to engineering design. After working with Dr. C on developing ideas how to center funds of knowledge in the activity, they concluded that they would leverage them through a discussion about airplanes, and designing a paper airplane, rather than just focusing on the science terms themselves. This prompted them to develop their lesson plan around airplanes (Field Notes)

Figure 4.2: Ciara and Denise during their lesson on weight, lift and thrust.

In their plan, they discussed that to introduce on weight, lift and drag, there needed to be a "brief discussion about any previous knowledge(s) the youth had about planes." By doing this, they were connecting previous, real world knowledge(s) to their experiences with planes. Denise and Ciara did this by planning to ask youth about their knowledge(s) about planes, and if they "have seen planes flying in the sky" from Great Lakes City Regional Airport (Lesson Plan Template, Denise and Ciara, Segment 4).

During the planning of this lesson, Denise and Ciara realized that they could not make assumptions about all youth having experiences flying or "seeing" planes, even if there was an airport nearby. In order to support all youth, regardless if they have flown or not, they decided to "show a video that demonstrates what a plane looks like and what it does, along with video of planes flying in and out of the local airport in their community." Their goal was to go to Great Lakes City airport and take video stills and pictures of planes of various sizes taking off and landing. From this video, teachers planned to prompt youth on discussing terms weight, lift and thrust regarding the observations in the video and connecting these to their own experiences. These then would connect to the activity on designing their airplane templates based on what they learned (Lesson Plan Template, Denise and Ciara, Segment 4).

By localizing Great Lakes City's local airport, Denise and Ciara are centering youth's community spaces as an important area of investigation. The PSTs also unpacked their views of what it means to fly and critiqued their own assumptions of who/what youth have flown. Rather, they planned their lesson to be equitable from the beginning and centering it on all youth regardless if they have flown or not. The PSTs realized that if they centered the discussion around having seen airplanes in the sky or on flying experiences, then this would create a culture of exclusion for youth who did not have this experience. In an attempt to be inclusive (and equitable) the PSTs planned on including a teacher-made video so that the discussion centered on what they observed in the video, instead of just on student experiences. However, through the video, then they planned to merge discussion on their experiences flying (if they have any). Here, PSTs were imagining a new way of leveraging resources as funds of knowledge(s) in the classroom. Not only did they plan on taking up their student's views of flying, but they created a video as a resource to support all youth in their learning. This video in turn also supported PSTs in emphasizing place and community, as the teachers are centering the youth's home community and teaching them about the transportation resources (as a type of knowledge(s)) available to them at Great Lakes City which they otherwise might not have learned about.

In another example, PSTs, Mary, Mariam and Angela developed a lesson plan related to connecting energy emissions in mid-Michigan to coal mining. They did this by connecting mining for coal to mining for chocolates in chocolate chip cookies. They began by investigating the local power plant in Great Lakes City. This powerplant provides electricity to the entire, but it is also known to the community that the powerplant contributes increased carbon emissions. The teachers planned to provide examples of how actions in using electricity in their homes and school could be related to the ways coal mining, produces coal that creates electricity to power up their homes. They included various ways to support a repertoire of visual/tactile and auditory components for youth with visual/hearing disabilities.

Their goal was for youth to connect the coal plant to lights in their homes. The teachers connected NGSS performance expectations by "using the cross-cutting concept of cause and effect to compare and contrast the "cookie" ecosystems before and after mining. Students will begin by predicting, then observing and explaining through work with a partner in "mining" the cookie. Students will brainstorm various ways to limit impact on environment and create plans to show government officials about their plans" (Mary, Mariam, & Angela, Final Lesson Plan).

In this activity, Mary, Mariam, and Angela centered their activity on a community issue, by connecting this issue to how youth could become engaged to change energy practice(s) in their communities. They also connect these views of teaching science with broader discourse practice(s) that support youth in science learning, such as, *Predict, Observe, Explain.* One of the most important learning parts of this example was not related to the activity itself, but the understanding of youth in their cultural communities. Once they presented this lesson to their teacher, the PSTs found out that a student in their field classroom was allergic to peanuts. Due to having learned this, they had to re-purpose the lesson to include materials that were not derived from peanuts. However, this experience helped to center a class discussion on how funds of knowledge do not only mean prior experiences, but also how they also how it includes their present and social futures in relation to the broader classroom community (Field Notes). Upon various iterations of planning to change the activity and viewing how these changes could constrain the "fun" they wanted out of the lesson, the PSTs decided on creating the materials out of baked clay. They purchased the clay materials and baked them in their homes for the final lesson. Here, they learned that resources are connected to ways youth could engage meaningfully in science learning, but that it also took "imagination and creativity for teachers to find the best ways to connect resources to learning" (Teacher Talk, Mary, Miriam and Angela).

Imagining resources in youth learning cases. In terms of imagining resources and learning from the youth learning cases, Sarah, Angela and Mariam worked with Christopher on unpacking his SUSU cell phone anti-bully app. Particularly, they looked at why it was important for them as teachers to recognize the resources that supported Christopher in making the app.

The PSTs discussed that Christopher made his anti-bully app “so that [community members] find their way to a safe place, somewhere you know, somewhere you want to go.” They noted “ [Christopher] wants to make sure people are safe especially in places they know and recur in their communities.” Most importantly, the PSTs realized that Christopher’s app is meant to help educate community members on recognizing “the signs and effects of bullying because not everyone talks about these signs in school or at least try to avoid them.” In terms of imagining resources, the PSTs noticed that community funds of knowledge(s) and upholding those knowledge(s)s in educative ways in community could help with providing safe spaces for community members in eradicating bullying. The PSTs noted: “having resources for when something happens such as having a GPS installed within the app helps to find safe places/emergency numbers to dial.” By doing so, he is providing a “tool to help eradicate bullying in his community.”

As future teachers, the PSTs realized through Christopher’s case that “bullying could lead to suicidal thoughts and or extreme danger in youth.” They developed imaginaries related to bullying by “recognizing bullying as not only an issue that affects classrooms, but that it can spread beyond its walls of my room to streets, and at the community level and that these are everyday concerns of youth.” In addition, by providing supports to youth like Christopher in their designs, PSTs could support “to localize the locations of bullying and teachers can become aware of these spots, but also the psychological effects these have on grades, focus in school, motivation and social life. Knowing these signs are important.” Finally, “we believe that it is important to teach student show to use these resources and when to ask for help.” (Sarah, Angela, Mariam, Speak up Step up, Christopher Case, Segment 3).

In this example, Sarah, Angela and Mariam's learning related to Christopher's anti-bully app supported ways that resources in the community were not only part of the engineering design, but that the design itself could serve as a type of resource for community as well. By recognizing the importance of local community safe spaces, emergency numbers and contacts, and other ways to promote knowledge(s) of community, the PSTs are implicating themselves as being part of supporting these resource connections between youth and communities.

Table 4.6 shows relationships between TE 400, the community (field) classrooms and youth cases with pedagogical imaginaries developed by PSTs. In the next section, I present the second finding of this chapter.

Table 4.6:
Relationships between TE 400, the Community (Field) Classrooms and Youth Cases with Pedagogical Imaginaries Developed by PSTs

Generative Learning from TE 400, Community (Field Classrooms) and Youth Cases	K-16 PSTs Science Learning Experiences	Types of Pedagogical Imaginaries (PI)	How PI's Support Youth Knowledge and Practice	What is Youth-Centered and Equity Oriented in this Example?
Imagining Teaching Practices	Unpacking meaningful science learning experiences, implicating their science teacher practice(s) as part of supporting meaningful experiences	Negative experiences in science led to limited understanding of topics, PSTs wanted to learn science and be able to teach it, uptake of out-of-school experiences and youth whole lives are important in science teaching	Recognizing out of school experiences of youth, recognizing teachers can support meaningful learning experiences based on their own teaching practice(s)	Creating classroom spaces that support student science learning experiences
Imagining Relationships with Students	Unpacking power and privilege and its existence in inequitable science teaching Recognizing identities and who we are and viewed as in our communities shapes the types of learning we want to engage in Planning to teach in support of individual youth' repertoires	Supporting all youth, regardless of their economic circumstances. Teachers are implicated in connecting youth to science Seeing individual student needs/identities in relation to broader classroom culture (e.g. AD's views of being selectively social)	Recognizing that social, economic and historicizing effects are at play in classroom learning Recognizing ways teachers can support individual student	Creating opportunities to open up science to all youth and create meaningful connections to it, but being mindful of power and privilege in making these connections
Imagining Resources	Unpacking science learning experiences initially related to having access to one "fun" science activities (e.g. frog dissection), generatively developed views that cumulative knowledge(s) of youth and home lives are also resources for learning	Connecting access to resources in science to resources as knowledge(s). Beginning where the youth are, setting problems in community and returning those as funds of knowledge(s) to build on later science experiences	Recognizing funds of knowledge(s) are important in past present and future and are cumulative	Resources are not only related to materials, but also implicate teachers in recognizing knowledge(s) as resources in teaching. Planning for these connections in their teaching is important.

Opportunities for PSTs to Make Sense of Youth's Knowledge(s) and Practice(s) in Assets-Based Ways that Centered Community, Home, and Classroom Resources and Movement of these Repertoires Became the Basis for Naming New Youth-Centered Equity-Oriented Practice(S)

In the previous finding, I critically unpacked how pedagogical imaginaries were developed throughout the course between spaces in learning from TE 400, learning from the field and learning from youth in their cases in relation to teaching practice(s), relationships with youth and uptake of resources in science teaching. For PSTs learning to observe, describe and imagine teaching practice(s), including how science is practiced, communicated, shared, shaped within the classroom, through a lens of unpacking classroom culture, supported PSTs in imagining expansive ways of how their own teaching practice(s) contributed to or limited opportunities for equitable learning. Taking the learning from the previous finding, I argue that PSTs in TE 400 developed two youth-centered, equity-oriented teaching practice(s) within their pedagogical imaginaries. These include: 1) explore youth and community science knowledge(s)/practice(s) to create classroom spaces that enact views and purposes of science and 2) creating classroom communities by planning teachers to relate with youth and enact by relating youth with each other.

In this finding, I also argue that teachers through critically unpacking, shaping and re-shaping their practice(s) towards becoming more youth-centered and equity-oriented created *equitable imaginaries*, or conceptual spaces where PSTs imagined new relationalities that implicated them in their classroom communities. These relationalities include ways they implicate themselves generatively in support of more equitable teaching experiences for their students in the field, or how they related students with each other in support of a more meaningful, collective classroom science experience. These also involved them shaping/re-shaping practices in support of the youth they will eventually want to teach. Through supporting equitable imaginaries, PSTs can be supported in construction of practice(s) that are dynamic and open up borders to science in critically consequential ways for their students.

In the next subset of findings, I will discuss each of the two co-developed practice(s) developed in TE 400 and how these were imagined through the problem-posing, fluid conceptual space of equitable imaginaries, seen in the engagement of PSTs through TE 400.

YCEO 1: Explore youth and community science knowledge/practice to create classroom spaces that enact views and purposes of science (for youth alongside communities). Through unpacking their own science learning experiences, PSTs realized how knowledge(s), practice(s) (and to some extent identity) is connected to how they saw themselves in science. These views then connected to broader views of science in their classroom field spaces. Observing and unpacking science practice(s) in these classroom spaces helped to shaped/re-shape their views of how youth in those classrooms meaningfully connected to their science learning (Field Notes). Alongside this, PSTs also critically examined how youth themselves (e.g. youth authored cases) named ways that their knowledge(s) and practice(s) were upheld by their science learning experiences. Eventually, PSTs recognized that the major link between science learning and youth were the ways they, as teachers, shaped and created spaces/opportunities to open borders to science. They did this by imagining and re-imagining practice(s) that were increasingly youth-centered in its shaping, but also critically upheld youth' views and purposes of science in its making.

To make the jump from recognizing youths' funds of knowledge(s) and practice(s) as important resources in learning science meaningfully to implicating themselves in supporting this work in their imagined practice(s), I look to equitable imaginaries. The generative unpacking of inequities existent within field classrooms supported the development of equitable imaginaries. By not being pressured to interact as teachers in the field, but rather supported to recognize and leverage critical ways that classroom communities, youth and teaching practice(s) interacted, these provided opportunities for views of equity to be imagined critically. Here, PSTs realized how links between youth learning in classrooms were tied to the practice(s) teachers upheld in support/or not of their youth.

One example of this connection was Carol's experience in Ms. C's 6th grade Spanish Immersion class. Carol discussed how being in Ms. C's class was "difficult" for her because Ms. C's practice(s) shift depending on what she is pressured to teach (Teacher Talk, Carol). In Ms. C's class, youth take after noon social studies and science in Spanish, while morning classes are in English.

According to Carol's Classroom Communities assignment, Ms. C in her classroom has created a culture of participation that is based on "money" (as positive reinforcement) given to youth who use Spanish Immersion. Those that do not use Spanish Immersion are not given this "money." However, Carol noticed that these rewards were not given to youth in the same ways during English-only instruction. Through this view, Carol saw that youth who spoke Spanish throughout instruction were rewarded more significantly than those that did not. Carol also noted that these differences in enacting classroom cultures between Spanish and English instruction created sub-cultures, where individual youth were being supported differently depending on how and when they used the language (Classroom Communities Part 1, Carol, Segment 3). Particularly, this was evident in how Ms. C would "get frustrated when youth who were supposed to speak Spanish didn't, or when they needed help and [Carol] could not help them because she did not know Spanish" (Teacher Talk, Carol).

Carol mentioned that this practice(s) needs to be disrupted so that Ms. C could open borders to science and opportunities to learn in meaningful ways (Teacher Talk, Carol). In addition, if Ms. C did not understand how youth science knowledge(s) and practice(s) contributed to ways classroom spaces upheld those views, then this could lead to inequitable science teaching. Instead, Carol discussed that the ways youth's science knowledge(s) and practice(s) contributed to classroom spaces, needed to be critically examined by the teacher and put in relation with the broader classroom culture in enacting views and purposes of science for individual youth and the classroom community (Teacher Talk, Carol).

One example of this relationality in her science field experience was when Ms. C was using Google Classroom in connecting learning from solar ovens to the practice(s) of modeling Carol noted:

> "When they made the solar ovens, they worked in groups…using Google Classroom to take notes… to experiment the different ways these could be made, and which model worked best, or which one didn't work as well. They had to brainstorm within their groups about these solar ovens and then put their heads together and cooperate to make a solar oven that reflected all of their ideas and put it to the test this was meaningful for me because I saw kids working together" (Classroom Communities Part 1, Carol, Segment 3).

In reflecting on this example, Carol noted that in this lesson, Ms. C first relied on Google Classroom to help youth develop explanations on their solar oven models, however after noticing that youth were talking in English and not Spanish, she asked them to "turn off their iPads and write down on the worksheet what she was worked on the camera projector" (Teacher Talk, Carol). In viewing this, Carol felt frustrated that Ms. C was not able to center the group discussion on the "hard work the kids did to build explanations on their solar ovens." Furthermore, because of her pedagogical choice to focus on the Spanish rather than on the ways youth together were enacting their views and purposes of science (with each other) through the discussion they were having on the explanation they were constructing on their solar oven models, did not help in creating a safe classroom space for their views and purposes to be legitimized.

This experience prompted Carol to create an equitable imaginary on the limitations of Ms. C's instructional practice(s) that day. Through this, Carol was able to safely critique and question the ways Ms. C was not supporting youth meaningfully in her classroom. In turn, Carol discussed that she would in her teaching create ways to merge the vocabulary limitations to Spanish in discussing models through the ways they developed their explanations. She would not have retreated them to whole-group. She discussed that she would place the youth in groups based on immersion proficiency and that those youth who she saw were not engaging meaningfully in the task, she would provide re-voicing or picture supports so that they could explain their thinking on the solar ovens. This equitable imaginary supported her in unpacking the ways her future teaching practices could/could not support exploring ways youth science knowledge and practices could be leveraged to create spaces that enact youth views and purposes of science. Carol noted that meaningful science instruction should be about the youth, not about the teacher (Teacher Talk, Carol).

Being in TE 400 provided a safe space for Carol to be critical of the ways her field classroom was not youth-centered and equity oriented. Through these criticalities she developed equitable imaginaries to support these youth meaningfully in their science learning (Final Interview, Carol).

YCEO 2: Create a classroom community by planning to relate with students and enact to relate students with each other through science. The second youth-centered, equity-oriented teaching practice that developed through the critical unpacking of knowledge(s) and practice(s) in TE 400, the field and the resources needed to support meaningful science learning was: create a classroom community by planning to relate youth and enact to relate youth with each other through science.

In the first finding of this chapter, I discussed major points related to how PSTs developed imaginaries around relationships with youth. These relationships began by recognizing youth learning experiences in the classroom and then unpacking their views and purposes of science, knowledge(s) and practice(s) through the Cases of Classroom Communities assignment. However, when PSTs began to plan for instruction in their field classrooms using the Science Talk (discussions in understanding science ideas and how they were connected to youth lives in relation to science content and practice(s) assignment), many PSTs noticed that although they better understood their broader classroom cultures relation to science learning, and individual students, they were not well prepared to understand how to relate the funds of knowledge(s) of students to each other in a science teaching moment (Field Notes). Maria, in her Science Talk focused on learning how youth in her 6th grade class discussed the interactions between living things. She prompted students to discuss how two different living things interacted. The following is an excerpt of Maria's (and Denise's) Science Talk transcript.

Maria: Does anybody have any thoughts about why squirrels go up into trees?

B: Because they're scared

Maria: Because they're scared?

Denise: So what are they using the trees for if they're scared?

L: Protection!

Denise: Protection?

K: To hide!

Maria: To hide, for protection…. Those are two ideas that I heard. Does anyone have any other ideas for why squirrels go into trees?

C: They probably put their food up there

Maria: To hide, for protection, they might put their food up there… I got three ideas, let's see if we can get two more

C: Protection from rainstorms?

Maria: Rainstorms? So maybe from the weather…

Denise: So not just protection from other animals, but protection from the weather too?

Maria: Hiding, protection from other animals, they might put their food up there, and protection from the weather… One more.

S: They can go to other places without being around people?

Denise: Yes!

Maria: Have you ever seen a squirrel jump from one tree to another?

D: Mhhmm

Maria: Yeah, it's pretty crazy, right? ….(directed at another student:) Have you seen that?

In this transcript example, Maria was prompting youth to discuss why squirrels go up into trees. Youth in their discussions related the interactions between squirrels and trees to being scared and hiding (which Maria combined and re-voiced as protection). Then, when she introduced the term protection, the youth promptly began to discuss protection from what? Here is when the youth connected their co-developed ideas from rainstorms to protection from other animals. Maria then again re-voiced their original idea of hiding (which prompted the discussion she engaged them in) and gave examples of what the squirrel needed to survive while hiding.

Finally, Maria discussed a fun connection to seeing squirrels hide from one tree another. However, in her observations of the students, she noted that one student was not engaging in the conversation around seeing squirrels jump between trees, even though some students did. This is when she turns back and directs to another student the question (more so in private) if they have seen squirrels jumping between trees (Science Talk Analysis, Maria).

Table 4.7:
Evidence Table from Maria's Leveraging Funds of Knowledge and Practices During her Science Talk

How did youth leverage resources for learning (funds of knowledge(s) + prior knowledge(s))?	How did students build on each other? Did they use student talk moves? Did they add to, argue about, etc. other student ideas?
"Students stated a variety of aspects of wildlife survival, evidencing that they have learned or thought about what is necessary for survival in the wild. They may have learned this through observation, TV, movies, or a variety of other sources."	"Immediately after this talk move, one student said that trees were good for protection, and another piggybacked off that to say that they need them to hide. **This shows that students were listening to one another and reflecting on their own knowledge(s) of the topic."**
"Since squirrels are a very common animal in this area, many of the students had thoughts and stories about squirrels. When asked to think more deeply about why squirrels need trees, they engaged in higher-level inference skills and move past the more obvious responses."	"Before this, student B said that squirrels use trees when they are scared. Student L built on this by saying that they needed them for protection, showing that they understood that being scared would mean that they need protection. After this, student C said that they may also use the trees for protection from weather, showing that they were listening to and engaging with their fellow classmate's thoughts." Maria prompted them by saying: "I got three answers, let's get two more" made students reflect more on the topic and encouraged students to talk more, even if their answers might be wrong
"In this example, student B was showing that they have prior knowledge(s) about squirrels interacting with other beings who may be predators to them. They are also showing that they know that a tree may be a good place for a squirrel to be safe."	"When student B made this observation, other students built on it by talking about the other thoughts they had about the necessity of trees in the lives of squirrels, which extends to ideas about animal's needs for shelter."

Maria's transcript and analysis of her work with youth relating squirrels with trees showed two important pieces related to ideas related to equitable imaginaries and relating students to science and students with each. The first is that Maria recognized that students had previous knowledge(s) about interactions between living things that they may have seen on TV, by observations or just in their everyday life experiences. She used these previous experiences to build her science talk.

Second is that she noticed that youth were “piggybacking” off each other’s responses, and so she implicated herself in developing this connection between students in their responses “[Maria] prompted them by saying: I got three answers, let’s get two more…this made students reflect more on the topic and encouraged students to talk with each other, even if students might be wrong” (Science Talk Analysis, Maria). By implicating herself and re-voicing the ideas the youth collectively came up with during the discussion helped to relate students’ experiences with each other, as well as with her teaching practices.

In relation to developing equitable imaginaries in these relationalities, Maria was also observing that one student was not engaging in the class discussion. She purposefully turned to that student and asked if they have seen squirrels jumping between trees. By doing so, not only was she engaging the youth during the discussion but noticing those that were not and creating relationalities to uphold their funds of knowledge through the discussion.

These two youth-centered, equity-oriented teaching practice(s) that developed from the work of the PSTs in the TE 400 course created connections not only in upholding and leveraging students’ knowledge(s) and practice(s) in science learning, but also implicating themselves by imagining equitable opportunities for students to relate science learning to each other in meaningful ways. In the next and final section of the findings, I will discuss how these YCEO practice(s) through an equitable imaginaries lens can help to support a classroom community where the culture of science is focused on upholding youth knowledge(s) and practice(s) in meaningful and equitable ways.

YCEO’s through equitable imaginaries: Supporting PSTs in challenging systemic inequities in their future classrooms. PSTs in TE 400 were prompted to critically unpack views of culture in their field teaching classrooms. They did this alongside their K-16 science learning experiences and the learning they took from the youth authored cases. All of these experiences helped to support PSTs in critically unpacking the interactions between the micro (e.g. youth knowledge(s) and practice(s) in the classroom; relationships with students) and macro relations (broader classroom culture; relationships between students in support of a meaningful science culture). Through this, PSTs re-imagined, shaped and re-shaped their practice(s) towards ones that were increasingly equitable and youth-centered—both in supporting views and purposes of science through meaningful relationalities in the classroom between students and the PSTs as their teacher. These imaginaries were also problem-posing and fluid because the dynamic nature of the practices they developed were all related to how they were able to uphold a meaningful science learning culture in their equitable imaginaries.

The way they did this as a way to shift the culture of power in science in their classrooms was through uphold an equitable imaginary view of the "we culture." The idea of "we culture" was prompted by reading Carlone and Smithenry (2014) in TE 400. In this view, students discussed that the "we culture" to them is not only one where teachers critically take up students' funds of knowledge and relate students with each other in their science learning, but that teachers also implicate themselves in this learning by critically examining ways that their teaching could eradicate existent inequities in the classroom (Field Notes, We Culture). In the following example, Sophia discusses what the "we culture" means to her:

> I do want to talk about a piece of student work that I saw on the wall [in my classroom] …There was no name on it, but the student labeled it "How Others Affect Me". There were names of various people on the paper, with the reasons they were impactful beneath. On one side the paper read, "President Obama" the reasoning below read "He supports Black lives with what is happening in the United States". On the other side it read

> “President Trump's reasoning was, “He bombed Syria”. I do not know how this discussion went as I was not in the class when this paper was made, but it sure sounds like an interesting, important, and meaningful discussion to have in a we culture classroom (Final Artifact Interview, Sophia)

This example, a very powerful one, shows how Sophia, unpacked critical relationalities of youth in her classroom community. Particularly in understanding how youth bridged their learning with experiences with power and privilege and how they may be systematically oppressed by society. Through this type of equitable imaginary lens, Sophia began to question how relationalities between students in the classroom could also uphold inequities existent in their lives. This was not about science learning, but how teachers could also humanize the experiences of their students.

Later in the semester, Sophia through her work in the field and building relationships with students found that the youth developed the artifacts she referenced in her final interview as a way to incorporate experiences of how politics and current events affect their daily lives. Building on the experiences of the youth who was a Syrian refugee to Great Lakes City, Sophia found out that Donald Trump’s recent imposing of a travel ban on majority Muslim countries affected immigration of her family to the country (Teacher Talk, Sophia). Building from the Syrian’s student’s experience, Sophia’s class felt the current administration was not out to support their best interest. Sophia further discussed that the majority of the youth in her field class were Black, but all youth collectively, felt that President Obama was supportive of the realities of the Black community through centering #BlackLivesMatter and other social movements important to them (Final Artifact Interview, Sophia). Sophia understood that to create a “we culture” in her classroom, realities and experiences of youth must be a part of learning, but her goal was to learn how to do this through her teaching (Final Artifact Interview, Sophia). Yet Sophia mentioned her un-comfortability discussing racial and classist dynamics because she was a middle class white female (Teacher Talk, Sophia).

In another example, discussed how power in society helped her unpack a “we culture” in her view of classroom communities:

> The way I [have seen] my classroom community disrupting power in society is how there are only two white youth in the class. As a result, the Students of Color end up having more power as a majority, and they tend to be more vocal in the space than the white youth. I did notice that [the class] tends to adhere to gender norms, with the girls speaking much less during science and math, and more during language arts… Ms. W does things to support these types of experiences so that it is fair for everyone (Final Artifact Interview, Maria).

Maria discusses important points related to her critically unpacking how disrupting power in society is connected to her views of the field classroom. The first is related to race dynamics. Maria noticed that participation of white youth in class was different from Youth of Color because the Youth of Color as a majority were able to voice their concerns more in/within the classroom space. In this, Maria recognizes that societally, white individuals have privilege over People of Color, and that in the microcosm of her field classroom, these oppressive practices are also at play. Problematizing Maria’s quote further, recognizing these participatory differences in race relations regarding the relationalities between students in the classroom does not necessarily mean that power in society has been disrupted. Even though the majority of the students were Black and were able to voice their concerns as a collective in the classroom culture, it does not mean this practice for them is reproduced in society. However, important here is that Maria recognizes the role that classrooms play within broader systemic hegemonic practices done onto Communities of Color. Her connection between her field classroom and race relations in society are significant. It is important that when opportunities of connection these broader systemic views of race interact with classroom cultures, methods courses can unpack them in critically consequential ways.

In further discussions with Maria, I found that she also unpacked several gendered dynamics in her field classroom, where girls talk less during science (and math) compared to boys (Field Notes). Maria then when discussing her equitable imaginaries related to how power plays a significant role in her field classroom stated "I would do all in my power to support my kids to all feel welcomed in my class. I think I see the power in learning about these issues in ways I didn't know would be beneficial for me" (Final Artifact Interview, Maria).

In reflecting on how PSTs as future teachers could implicate themselves in challenging beginning inequities in their science classrooms, during TE 400 they named equity as:

(1) Giving equal opportunities for all youth to learn
(2) Not making assumptions or essentializing cultures of youth
(3) Giving youth choices and access to science
(4) Supporting youth backgrounds, learning levels, context of learning that help support differentiation in instruction
(5) Making materials accessible to youth, hands on and using multiple representations
(6) Providing youth with individualized, equal opportunities to succeed in providing fairness in student participation (Field Notes, Segment 4).

One of the challenges that the PSTs developed as they built on equitable imaginaries in their practice was unpacking what it meant for them to incorporate the "we culture" in the lesson planning. Table 4.8 shows the “we culture” checklist which was co-developed with PSTs and Dr. C during one of the classes in segment 4. In unpacking the different ways that “we culture” functions within their classroom spaces, the PSTs noticed that there were ways that they could recognize if they were attending to these aspects of the “we culture” in their classrooms. They included aspects related to planning for participation of diverse learners, expanding diverse outcomes of the lesson and unpacking ways they, as teachers, could disrupt power dynamics in their classrooms through their teaching practice(s).

Table 4.8:
TE 400 "We Culture" Checklist

Category	Yes	Sort of	No
I bring a "We culture" to my lesson by…			
Creating opportunities that value individual youth for who they are and what they know/have experienced	x		
Positioning youth as experts (e.g., Students are recognized for what they **know**, and their **expertise** is used to **help others**)	x		
Valuing youth' ideas and experiences just as much as the science I have to teach	x		
I have planned for different participation strategies to support different learners by...			
Using at least two of the following participation structures: whole group, small group, think-pair-share, personal reflection time	x		
Using multiple methods for representing ideas (in my *teaching*), such as talking, writing, drawing, images	x		
Using multiple methods for youth to represent their ideas such as talking, writing, drawing	x		
Valuing linguistic diversity, or use different languages to support meaningful learning (English/Spanish)	x		
I support expanded learning outcomes in the lesson by...			
Providing youth with different opportunities to show/share what they know/have learned (beyond the typical test)	x		
Providing youth with opportunities to use their knowledge(s) in meaningful ways	x		
Planning for youth to use their funds of knowledge(s) is a part of the science activity	x		
Planning to utilize what experiences student bring to learning	x		
Planning recognize and celebrate youth' scientific thinking beyond only the right answer (e.g., thinking divergently, solving problems, making unique observations)	x		
Providing time for youth to discuss their ideas, findings, and identify questions that could lead to future investigation. Include consideration of: wait time, different discursive strategies, and potential contributions.	x		

Table 4.8 (cont'd)

Category	Yes	Sort of	No
I plan to disrupt traditional power dynamics by..			
Utilizing participation strategies help girls and boys share the floor equally.	x		
Supporting and valuing the use of multiple student languages (e.g., youth for whom Spanish is their preferred language are encouraged and recognized for using their Spanish to help others and in their own learning. Dominant American English is not the only form of acceptable language.)	x		
Leveraging youth' cultures as a part of doing and learning science	x		
Planning specific ways to disrupt power hierarchies (racialized, gendered, linguistic, etc…) that I have noticed operating in the classroom community	x		

This co-imagined equity checklist became a tool for teachers to plan for supporting equitable imaginaries in their future classrooms. This checklist is the final compilation of PSTs developing imaginaries over the course of TE 400 in how they shaped, re-shaped and critically unpacked and upheld youth-centered, equity-oriented teaching practices in their field experiences and how they implicated themselves in this work.

Discussion

The learning from this chapter is multifaced and multidimensional in bringing together ideas that challenge foundational inequities PSTs may reproduce early on in their science teaching. PSTs through participating in the TE 400 course and seeing their experiences in K-16 science education alongside their field classrooms, provided expansive and layered opportunities to critically unpack what it means to leverage youth knowledge(s) and practice(s) in science education. Through this work, PSTs were able to see that the interactions between imaginaries produced in TE 400, the field and with the ways they learned critically from the youth learning cases were dynamic and expansive. The dynamic nature of these imaginaries provided critical opportunities to see the micro (histories, identities, knowledge(s) and practice(s) and macro (classrooms, practices that uphold equitable science teaching) scale interactions in science teaching. The expansivity of this work allowed for PSTs to center youth, their histories and their lives against the broader institutionalized culture of science by shaping and re-shaping these views over the life of the methods course.

These experiences prompted PSTs to see how emerging relationships with youth and between youth and how these interacted in the broader macro—classroom community could reproduce inequities already existent in society. Although PSTs in this paper developed two important practices that were generated through the examination of their views of teaching practices, relationships with students and critically examining what it means to leverage resources as teachers in their classrooms, the greatest impact is how equitable imaginaries can be developed towards increasingly becoming youth-centered and equity oriented in their practice. Through this end, they implicated themselves in the connection between science knowledge(s) and practice(s) and youth knowledge(s) and practice(s) in upholding views and purposes of science through the relationalities they notice and seek to connect with in their teaching practices. In the fluid, problem-posing spaces between the methods course and the field, the PSTs were able to critically examine what these connections looked like, and even became critical of how their mentor teachers limited this uptake in their own classes. PSTs also designed tools (e.g. "we culture checklist") to check themselves on how their future planning and enacting are indeed centered on youth in their classrooms. Providing a safe space for PSTs in a methods course to view these foundational inequities and provide opportunities to generatively unpack how they are implicated in this work is critically consequential and theoretically necessary.

One of the important points in this chapter is the importance of challenging normative views of student—teacher relationships in science teacher education. These views have historically centered on individual interactions. In the framing of this paper, I echoed Dominguez (2014) and Laudo Castillo's (2014) work on fluidity. Because methods courses are usually centered on the solid method of exchange and one-way interactions, PSTs often do not have opportunities to critically examine how practice(s) are developed and shifted depending on the culture that is reproduced and relationalities of students within their classroom communities. Centering methods courses on developing imaginaries as practice through a view of fluidity, supports this challenge.

This chapter also upholds youth views as experts in their homes and communities. In combining these expertise(s) in the classroom community, teachers become an important bridge between science and youth lives. By implicating themselves in this work, PSTs can view themselves as participatory in this stance of connecting youth to science. By politicizing knowledge(s) and practice(s) of youth in classrooms, PSTs can create cultures in classrooms that uphold youth ways of knowing and being in equitable ways. All without sacrificing these important connections for the sake of centering the culture of power in science. Science learning in this piece expands what it means to leverage resources in science classrooms. Resources are not only materials, but the careful unpacking and leveraging of youth funds of knowledge and repertoires of practice in science education.

Learning about their roles in reproducing power and oppression were also important in this preservice course. Discussing race, class, and gender dynamics and how these may be mirrored in the classroom culture is critically necessary. Although all the PSTs did not implicate themselves in these racial, class and gendered structures, some PSTs either had K-16 experiences that they knew were connected to racial, class and gendered dynamics or they were able to unpack them in their field experiences and analyze them through their developing equitable imaginaries lens in their TE 400 course. Important here is how PSTs critically unpacked classroom communities and norms of learning in the field, and saw these dynamics were related to the positioning of youth in society. Sophia's analysis of the Syrian Refugee student's work is an example of that.

The relational underpinnings of who has the knowledge(s) and who holds the power is important in creating equitable opportunities. Further studies are needed to unpack what this means and how these shape race, class and gendered dynamics in classrooms. Particularly because the majority of the PSTs were white, middle class females, a demographic overly represented in teacher education, but understudied along critical race lines. Furthermore, there needs to be more studies on how white preservice science teachers view and relate to Students of Color, especially as we know power and privilege in our society is driven by race and white supremacy. Preservice teachers need to be given opportunities to view these issues of power and privilege through their field classrooms, but they also need to be provided with safe spaces to interrogate these issues where they will not be critiqued for the views they hold (even if they are racist, classist, or gendered). In addition, this paper shows that more work needs to be done to center race and racism in science education, and more specifically in how whiteness and views of race gets reproduced within the culture of power when majority white, middle class teachers teach predominately Students of Color.

Overall, the outcomes in this chapter provide a *beginning* framework of how to center youth-centered, equity-oriented imaginaries in a science methods course. I emphasize that this is an attempt to do so and it is only the beginning.

Future Research

Future research is necessary to continue developing this work in science teacher education. I look to two future possible research areas with this work. The first is creating tools that support developing pedagogical imaginaries through a framework of imaginaries as practice. I look to create ways that PSTs can critically and generatively unpack views of youth-centered, equity-oriented science teaching practices through systematic cycles of inquiry into practice. Particularly, these tools can be more purposeful in supporting the shaping and re-shaping of practices over the course of a science methods course, or even in building program coherence within a teacher education programs. Table 4.9 shows possible tools that could be developed in support of YCEO practices in science learning to teach.

Table 4.9:
Future Research on Tools that Bridge YCEO's with PI's in Science Teaching

Type of Tool	What the Tool May Look Like	Goal of the Tool
Science Experience Tool	Ways to showcase high and low moments in science learning experiences K-16	Connecting previous K-16 experiences to beginning views of teaching science in methods course
Classroom Communities Tool	Critically unpacking classroom communities and the culture of science in them.	Connects youth knowledge(s) and practice(s) to ways PSTs examine their participation in science class
Relationality Tool	Tool that supports critically unpacking relationships within the classroom.	What do relationships look like between students, between teacher and student and how do PSTs see these developing relationships contributing to meaningful science learning
Discourse Tool	Tool that supports critically engaging youth in science talk conversations that take up elements of relationality	Provides opportunity to delve deeper into how science content can be merged with student-led discussions and how teachers can hybridize these to create meaningful science learning experiences.
Enacting Equitable Imaginaries Tool	Critically unpacking imaginaries throughout the methods course by examining the learning spaces between the field and the methods course.	Provides opportunity to combine developing equitable imaginaries and practice(s) through a lens of power and privilege throughout the ways the field and methods course interact

The second area of work I would like to push forward is supporting this view of youth-centered, equity-oriented teaching practices in classrooms with future Teachers of Color. I would like to understand how views of equity are supported, challenged and shaped by the racial and cultural diversity of PSTs in the uptake of youth knowledge(s) and practice(s) towards equitable imaginaries. Overall, implications for this work calls for upholding youth' home/community/ and family repertoires of practice(s) , personal lives and pursuits as a critical part of learning to teach of science.

CHAPTER FIVE:
"IT'S ABOUT THE PROCESS": THREE PRESERVICE SCIENCE TEACHERS ENACTING THEIR VIEW OF YOUTH-CENTERED, EQUITY-ORIENTED SCIENCE PRACTICES

In the title of this chapter, Carol, a preservice teacher who taught a six-week engineering unit in a 6th grade Spanish immersion classroom at Liberty School discusses her learning to teach as a process. For her, "it's about the process" is a cumulation of her views of how to support youth in learning science in youth-centered, equity-oriented ways. Her practice(s) were shaped not only by *understanding the process* of student's engaging in science meaningfully in applying problems of community to science learning, but also, how her *teaching process* developed over time by understanding these problems of practice(s) within her classroom setting. In applying how/what she learned about youth in her science methods course at Liberty School, this allowed her to (re)shape her teaching to generatively become more youth-centered in her classroom practice(s) .

Learning to Teach as a Process

Through the years, research on teaching and teacher education has provided important avenues to professionalize its practice. One of teacher education's greatest challenges is to understand how clinical aspects of practice support novices in developing teaching practice(s) in the classroom (Grossman, Hammerness, & McDonald, 2009). With increased efforts of professionalization, teacher education has seen tremendous shifts in what practice(s) are necessary for teaching. In the 1980's researchers focused on knowledge(s) demands for teaching, including work on content knowledge(s)/pedagogical content knowledge(s) necessary for teaching (Ball & Bass, 1999; Shulman, 1986). Later, in the late 00's shifts focused towards more cognitive views of teaching by emphasizing less what teachers need to know in their content areas and focus more on *the process* of learning to practice —towards why/how/in what ways knowledge(s), skills and professional identities are developed (Grossman & McDonald, 2008; Grossman et al., 2008).

For teacher education, this focus on developing practice(s) as part of learning to teach is critical and has had some history in variation of thought. Some scholars argue that educational theory and practice(s) should be distinct from each other and learned through separately (Smagorinsky et al., 2003). Others argue that there should be an interdependence between courses that support this development of theory and practice(s) (Rosaen & Florio-Ruane, 2008). I argue for one that involves a deep interplay between theory and practice(s) through re-designing and critically examining field placements in relation to teacher preparation coursework (e.g. views from Grossman et al., 2008).

Grossman et al. (2008) argue that focus only on content knowledge(s) that emphasizes separation between theory and practice(s) may shadow other important skills in teaching such as "orchestrating instructional activities, and the relational work involved in creating classroom communities "(p. 273). Lack of understanding the practice applications of theory to foster instructional activities and relational work with youth –can create possible tensions in improving teaching practice(s) over time. Particularly because in focusing on content-based instruction without examining the power existent in classroom spaces, and the power that the content reproduces within the classroom, can further exacerbate issues of power and privilege between youth and the discipline (for connections between science and views and purposes of science in classroom see Chapter 3).

Science education has also seen many shifts from supporting a deep content knowledge(s) in science towards shaping practice(s) for teaching. Previously, teachers were pressed to transform their subject matter knowledge(s) into teaching by critically reflecting and interpreting subject area knowledge(s) (Abell, 2008). Transforming these includes critical understanding of youth' developmental levels, prior knowledge(s), misconceptions that allow to tailor science instruction to this (Abell, 2008). However, now, there is also an alignment with the stance of reflective practice(s) between teacher education and the field. For example, take Ambitious Science Teaching Practices (Windschitl et al., 2011). Here, teachers are supported to develop ambitious practice(s) that focus on developing scientific ideas over time and improving on those ideas through classroom discourse. By focusing on the idea of practice(s), then teachers have "a principled way of doing the work that can be identified, learned, and continuously improved over time" (Ambitious Science Teaching, 2018).

However, Windschitl and Calabrese Barton (2016) conclude that ambitious science teaching research has not systematically taken up equity-related concerns and this is a large gap that needs to be addressed in the ways novices (and PSTs develop these equity-related practice(s).

In thinking more broadly about of equity in classroom practice(s), Cochran-Smith and Lytle (1999) reminds readers that the teaching profession is forever tied to the purposes of schooling and educational change. These are driven by constantly (re)defining conceptions of policy, research and practice(s). These (re)definitions make it difficult to agree on a specific set of practice(s) that constitutes effective teaching. Cochran-Smith and Lytle's (1999) stance, although geared at the differences between teacher education programs in developing structures to support PSTs in practice(s) , also pushes to understand the critical juncture between theory and practice(s) in supporting PSTs to (re) define practice(s) through the relational work involved in their classrooms. Particularly, in how these support equity-oriented classroom practice(s). This notion is critically important and theoretically necessary.

I argue for a type of conjoining of theory and practice(s) that supports science teaching that is youth-centered and equity-oriented within the scope of “orchestrating instructional activities, and the relational work involved in creating classroom communities” (Grossman et al., 2008). Particularly in looking at how different classrooms communities, during field experiences, can shape enactment of youth-centered, equity-oriented, science teaching practice(s). In looking at how PSTs localize and (re)shape science content and teaching practice(s) to support youth in a local Spanish Immersion School during a six-week unit on teaching engineering for sustainable communities. Understanding the practice(s) implications of working in classrooms and the challenges in enacting practice(s) in youth-centered, equity-oriented ways can help us understand how developed practice(s) that are centered around youth and for youth can be shaped by the local practice(s) in classrooms when teachers engage in enacting practice(s) in their field experiences and what can be done to support this. The research questions under investigation are:

1. In what ways do preservice elementary science teachers enact views of youth-centered, equity-oriented teaching practice(s) in an engineering unit focused on sustainable communities.
2. How are these youth-centered, equity-oriented teaching enactments shaped by local contentious practice?

Theoretical Framework

In the next section I will describe the theoretical framework for this study: Enactments as Practice.

Enactments as Practice

For enactments as practice, I draw upon social practice theory (Holland & Lave, 2009) and pedagogies of enactment (Grossman et al., 2008) to guide this study.

Holland and Lave (2009) discuss that social practice theory "integrates the study of persons, local practice(s) and long term historically institutionalized struggles" (p. 1). I chose this theory because of its potential to "understand[ing] and explain[ing] real, every day, situated activity in its concrete, material detail" (Roth, 2006, p. 22) while also "emphasizing historical production of person in practice and pay[ing] particular attention to differences among participants, and to the ongoing struggles that develop across activities around those differences" (p. 1). In this paper, understanding the differences among the three preservice teacher participants will allow me to see how their enactments are shaped by local practice(s) .

In their work, Grossman et al. (2008) discuss how pedagogies of enactment focuses on the core practice(s) of teaching. These core practice(s) include: (1) practice(s) that occur with high frequency in teaching; (2) practice(s) that novices can enact in classrooms across different curricula or instructional approaches; (3) practice(s) that novices can actually begin to master; (4) practice(s) that allow novices to learn more about youth and about teaching; (5) practice(s) that preserve the integrity of complexity of teaching; and (7) practice(s) that are research-based and have the potential to improve student achievement (p. 277).

Findings in Chapter 4 indicate that PSTs in TE 400 developed imaginaries towards enacting two practice(s) geared at supporting youth-centered, equity-oriented science teaching. *These included: (1) explore youth and community science knowledge(s)/practice(s) (s) to create classroom spaces that enact youth views and purposes of science and (2) create classroom communities by planning to relate with youth and enact to relate youth with each other.* These practice(s) support a collective approach to understanding how teaching practice(s) can be essential in the creation and maintenance of productive classroom communities that upholds youth' knowledge(s) and practice(s) in science, but that also understand the relational power differential between youth, youth and teachers, and the epistemic discipline of science.

By understanding how enactment of these youth-centered, equity-oriented practice(s) function within classroom spaces we are "allowing novices to learn more about youth and more about teaching" (Grossman et al., 2008, p. 272) within a context of "orchestrating instructional activities, and the relational work involved in creating classroom communities" (p. 273). However, it is not only about orchestrating types of instructional activities, but also how do they implicate themselves in mitigating broader, systematic (often inequitable) practice(s) in science learning.

This is why I chose social practice theory alongside pedagogies of enactment—in order to understand how local practice(s) shape science teacher education. I am interested in understanding how real, every day, situated practice(s) can contribute to ways that PSTs approximate, shape and reshape classroom enactments as a process towards generatively becoming more youth-centered, equity-oriented in their teaching. This with a particular focus on approximation of practice, or opportunities to "rehearse and enact discrete components of complex practice(s) in settings of reduced complexity" (Grossman et al., 2008, p. 283). This opportunity to engage in pedagogical enactments within classrooms spaces where they are not yet classroom teachers but have a long-term relationship in the space with youth (over six months), allows PSTs with unique opportunities to rehearse and enact these complex practice(s) with reduced complexity. This not only allows to practice, but also learn to shape and (re)shape their practice(s) as a process of learning to teach over time.

Holland and Lave (2009) refer to “two forms of history,” the personal and institutional. The authors argue these forms of history, “history in person” and “history in institutionalized struggles”, are always present and in relation through the activities individuals participate in. Hence, these histories are carried out via personal experiences in local practice(s), and in turn these are enacted against the broader cultural and historical narratives in which they occur. Given this study is situated during a six-week implementation of an engineering unit focused on supporting youth in solving local community problems through engineering design (NGSS Lead States, 2013), understanding differences—and relationalities—in the ways youth engage in this unit can shape pedagogies of enactment. This is why *enactments as practice* can be an important framework to understand how these approximations of practice(s) can happen in relation to how teachers imagine and enact their own teaching and how these are shaped by local practice(s) .

In understanding how to view these approximations in relation to tensions that may occur in local practice(s), I look to Holland and Lave’s (2009) view of local contentious practice (LCP). According to Holland and Lave (2009) local contentious practice lies at the heart in relations between history in person and history in institutionalized struggles, primarily because local practice(s) comes about in the encounters between “people as they address and respond to each other while enacting cultural activities under conditions of political-economic and cultural-historical conjecture” (p. 3). Understanding how local contentious practice (in ways that classrooms are already shaped by political/economic/cultural-historical forces) shapes teaching enactments can help to see ways local conflicts and forces shapes the relationships between local practice(s) and the person in history (Holland & Lave, 2009) for the PSTs. This may happen at one time, or generatively as they try to enact youth-centered, equity-oriented teaching practice(s).

In this paper, I view teaching in youth-centered, equity-oriented ways and how these are connected to cultures of classroom communities (since they had over a six-month history in their respective classrooms from field experiences in TE 400). I will however, focus on how their views of youth, teachers, and classroom communities, and the types of practice(s) they want to engage in were structured or (re)structured by local contentious practice. The goal is to start with understanding the struggles of particular times and places that relate to broader structural forces within relational contexts (Holland & Lave, 2009). In addition, how do these contentious struggles shape views of ways societal institutions (like schools) and discourses in science become disproportionate against minoritized racial, ethnic, class, and gendered groups.

Methodology and Methods

Critical Ethnographic Case Studies

I employed critical ethnography as my primary methodology for this chapter because it is a humanizing methodology for conducting research for participatory critique, transformation, empowerment and social justice (Paris & Winn, 2013; Trueba, 1999). This methodology "blurs the lines" and exposes, critiques and transforms inequities associated with structures and labeling devices inherent to fundamental dimensions of research analysis that involves race/ethnicity and gender dynamics (Calabrese Barton, 2001). Particularly, this approach allows me to understand complex, social phenomenon in relation to participants. Working with PSTs over the course of 13 weeks during their TE 400 course and then for over 6 weeks in a co-mentoring capacity (with other graduate youth and Dr. C) through this teaching experience, helped to reveal historical and cultural practice(s) guiding participation, identity formation, and action taking in their views of teaching. Through our work together in the methods course (see Chapter 4) the PSTs understood the importance of viewing science through a cultural lens and how their work as teachers could help open or close borders to the culture of science. Also, being that the three PSTs in this study are white, middle class females and I being a Latina, lower income female, we shared openly and without fear of repercussions, our views and positionalities from a space of mutual understanding. Although I had a type of epistemic power because of my work in co-developing materials for the engineering design unit (henceforth referred to as EDU), and being a science teacher educator, I continuously aimed at co-developing understandings with them because I viewed them as teachers and experts in their own classrooms. Although, I added my perspective from my work in communities and from my own culture repertoires, I always valued the PSTs' knowledge(s) of their youth and classroom cultural communities.

Hence this work allowed us to transform inequalities from multiple perspectives (Trueba, 1999) in their teaching. Working over six weeks, 7-10 hours each per week, I helped them to plan, enact, and debrief on their work during the EDU. These meetings helped us to "politicize" the interaction between us (me and PSTs, PSTs and their mentor teachers and PSTs with youth and intersections amongst these interactions). I did this grounded in the belief that these relationships are never neutral. Also, I focused much of my case study development work through understanding anecdotes of teaching experiences during the day. These happened mostly in passing, or through PSTs own views of their teaching in field notes that they themselves wrote about their teaching experiences. Van Manen (1994) discusses how teachers "tend to tell anecdotes about things that happened during the day, and how they reflect on these stories with others, thereby discovering what they are capable of seeing and what sense they can make of pedagogical situations (p. 157). Although this paper is not a phenomenological study, I do view lived experiences as important in the ways PSTs experienced and learned from their teaching enactments. Data gathered and interpretations on these lived experiences happen through various methods gathered throughout the study.

Research Context and Approach

This study is situated in three sixth grade classrooms at Liberty Spanish Immersion School in Great Lakes City, MI. Great Lakes City is an urban area hit hard by economic recessions and subsequent population decline experienced across the state (Bureau of Labor Statistics, 2011; U.S. Census, 2010). This study was conducted from January 2018-April 2018 after the three PSTs participated in TE 400 (see Chapter 4). In TE 400, teachers were placed for 20 hours of observation in classrooms, and this study is a follow-up to how they enact an EDU focused on engineering for sustainable communities (see Chapter 2 for further explanation on this topic) in the classrooms they built knowledge(s) of/in/with during their methods course.

Although this paper is about the PSTs enactments in local classrooms, it is important to discuss the EDU and its relation to this work.

The EDU was co-developed by Dr. C (Principal Investigator at Midwestern Research University) and colleagues (including graduate students) as part of a larger National Science Foundation (NSF) study which took learning from youth engagement with science and engineering practice(s) in out-of-school spaces and transformed them into lesson plans for teachers to engage middle school youth in engineering for sustainable communities. In Spring semester 2018, our research team planned an EDU implementation at Liberty Spanish Immersion School (Ms. W, Ms. C, and Ms. L which in this paper I refer to as mentor teachers). Because the PSTs from TE 400 were most knowledgeable on the culture of power in the science classrooms we would implement in, Dr. C opened up the opportunity in January 2018 after TE 400 to PSTs interested in supporting the implementation of the unit and leverage their expertise to support the youth in these classrooms during the EDU. This unique opportunity provided a space for me to conduct the study in this chapter, as it opened spaces to understand how PSTs ’ engagement with how approximations of practice (Grossman et al., 2008) could be seen through their support of youth during the implementation. After seeking permission from Dr. C to engage in this sub-set study within the larger engineering unit implementation, I worked with the PSTs and mentor teachers on developing days and times when they could support the teachers in an instructional role. This provided more opportunities to see/do science instruction in ways that the traditional methods course did not, and it also supported the mentor teachers with the new engineering unit with adults the youth were already comfortable with in their classroom.

Role of Researcher

Given my work with the engineering design project, I would like to document my role as the researcher in supporting the implementation. During the six-week implementation, we had approximately 90 youth participants total in the three mentor teachers’ classes. Carol (Ms. C), Maria (Ms. W) and Sophia (Ms. L), the three PSTs in this study, worked to support the implementation in their respective field experience mentor teacher’s classrooms.

Supports for implementation were different depending on the needs of the teacher. From the engineering unit research standpoint, PSTs were asked to complete field notes of their noticings during the implementation, regardless if they were teaching or not. In addition, they were asked to support with troubleshooting materials (e.g. fixing copper tape or batteries during electric art) during implementations so that teachers could focus their instructional supports to developing practice(s) or DCI’s in the unit.

As part of the teaching portion of this research study, I requested mentor teachers that PSTs be allowed to teach one lesson each week from the unit. This lesson would be one they felt comfortable with and that they had an opportunity to pre-plan with me and debrief after the implementation to discuss any noticings and experiences related to how they are developing teaching practice(s) or challenges during enactment. The PSTs were not obligated to teach the class if they did not feel comfortable, but over time it became the case that their instructional time increased as they were able to build experiences in their teaching.

My goal was to have increasing opportunities of approximations to practice (Grossman et al., 2008) during the unit in whichever way possible. I initially began the unit thinking that the mentor teachers would support the PSTs in their one-day enactment and then ask for engineering support throughout. However, over the course of the implementation, as the EDU became increasingly centered on youth and community practice(s), the mentor teachers relied heavily on the PSTs' expertise gathered through TE 400 on merging youth practices with the science and engineering practice(s) and DCI's of the unit. In addition, having access to one-on-one support for pre-planning and post-planning meetings with me helped the PSTs to develop greater expertise in the unit, which the teachers heavily relied on.

Hence, the idea of science expertise and science for whom in this implementation was flipped and two-fold. The first was through how mentor teachers were pressed by curriculum materials and tools the unit provided to take up on youth's funds of knowledge (Moll et al., 2001) in critical ways as they engaged in problems and solutions of engineering design. The teachers felt that they were not prepared to understand how to hybridize these practice(s), so they relied heavily on the PSTs ' expertise in this arena. In one professional development session, Ms. L referred to herself as a "teacher learning from PSTs " (Week 3, Implementation). This experience positioned the PSTs as experts during the unit in ways that they were not during their

TE 400 20-hour observations—this created further relational spaces to build connections with youth.

In addition, working at Liberty, which is a Spanish Immersion School, provided avenues to problematize not only the ways PSTs enacted practice(s) during a science unit, but also how these were intersected ways that supported a Spanish immersion classroom setting. Table 5.1 includes information on PSTs, mentor teachers, descriptions of the type of classroom they were in, and general description on the types of instruction they each enacted during the unit which were ultimately negotiated between the PSTs and mentor teachers as a result of their work in the unit.

Table 5.1:
PSTs, Mentor Teachers, Classrooms and Roles

Preservice Teacher	Mentor Teacher and Experience	Grade and Type of Classroom	Approximate hours of preservice teacher support per week	Type of support
Carol	Ms. C (first year teacher, but did her student teaching at Liberty with the same youth the year prior to this enactment)	6^{th} grade full Spanish immersion	Carol did not do full classroom implementations but supported small groups of youth for approximately 3 hours per week out of a 5 day- 1 hour a day unit implementation each week.	Since Carol was not a Spanish speaker and could not instruct the materials in Spanish, her teaching experiences were different than the other two teachers. Carol mostly supported youth in trouble-shooting materials during implementation, designing sketches of designs and defining criteria and constraints of design based on community problems and perspectives. She was often placed to support youth with disabilities and those who did not engage well, according to mentor teacher, in the immersion setting.
Sophia	Ms. L (over 20 years teaching)	6^{th} grade non-immersion	Sophia worked approximately 6 hours per week supporting teacher instruction and from the beginning was positioned as a co-teacher throughout unit implementation.	Ms. L from the beginning of the implementation positioned Sophia as a co-instructor in the classroom. Although Sophia planned on doing her own instruction by Week 3, Ms. L instead directed her to co-instruct the class with her and to "chime in" all the days that she supported her during implementation.
Maria	Ms. W (approximately 7 years teaching, was a prison guard prior to teaching)	6^{th} grade non-immersion	Maria worked approximately 8 hours per week in supporting teacher instruction, and within the 8 hours provided 3-4 hours of instructional time.	During non-instructional time, supported groups of youth in developing designs. Students were set up to work in groups in this classroom from the beginning which allowed Maria to work closely with groups as part of her instructional activities. During her whole-group instructional time, she directed activities and taught the EDU herself. The teacher relied heavily on her taking over the class as Ms. W had personal matters which prevented her from being at school many days during the implementation.

Data Generation

Data were generated over the course of six weeks and included participant observation (30 hours each), conversation/group talks (7 hours each), one final interview with each preservice teacher (3 hours total), field notes (researcher and preservice teacher's own), classroom enactment (7 hours each/ 6 weeks) and interviews between PSTs and youth to find out about funds of knowledge(s)/repertoires of practice(s) to support learning during EDU (6 hours). Data generation allowed me to focus on developing individual cases, which "involve more than one unit, or object, of analysis" and this allowed me to "focus on different salient aspects of [each] case" (Scholtz & Tietje, 2002, pp. 9-10). See Table 5.2 for data forms and specific data generation strategies.

Table 5.2:
Data Forms and Specific Data Generation Strategies

Data Form	Specific Data Generation Strategy	How did I employ these methods?
Participant Observation/ Field Notes	Observed PSTs support teachers during classroom implementation of EDU and over the course of their own implementation. Observed PSTs implementing EDU (approx. 3 hours per week/6 weeks= 18 hours total for three PSTs)	Participant observation supported to understand how/in what ways teachers were implementing youth-centered, equity-oriented teaching practice(s) and how these were shaped by classroom practice(s) . Days that they did not teach allowed me to see the various roles that they were supported in developing throughout implementation (5 hours per week/6 weeks = 30 hours of implementation)
Conversation Groups/ Teacher Talks	Met with PSTs for 30 minutes before weekly implementation to plan and 30 minutes after implementation to de-brief about implementation over the 6 weeks (1 hr a week/6 week= 6 hours total). Here PSTs discussed enactments and ways they would shape/reshape practice(s) based on how they made sense of their teaching experiences. Conducted final 1-hour conversation group interview which each preservice teacher to understand the overall learning from the experience.	By doing weekly pre-post planning meetings, I was able to understand in-the-moment interactions or ways they made sense of experiences in the classroom. These sessions were what mostly gave rise to understanding tensions between the types of implementation the preservice teacher wanted to see and how local practice(s) shaped these enactments. The final 1-hour interview helped to understand overall learning from the experience and served as a way to triangulate the other data sources.
Artifact Think Aloud	Some PSTs used their own materials to support types of enactments which they felt the curriculum itself did not support, so I met with PSTs (30 minutes) to understand when these were happening.	Because PSTs wanted to use curricular materials in ways that best supported their youth, they were free to change or shift some of the teaching based on their experiences. If they did this, I asked to see artifacts and asked for a think-aloud session to understand why and how they used these think-alouds.
Artifact Collection/ Teacher Field Notes	Collected pictures and videos of enactments as well as teacher-led field notes to better understand experiences based on their own sensemaking of youth ideas throughout unit	This helped me understand first hand, ideas or perspectives which otherwise they did not feel comfortable or supported in leveraging during the unit enactment.

Table 5.2 (cont'd)

Data Form	Specific Data Generation Strategy	How did I employ these methods?
Science Talk between Preservice Teachers and Students	Preservice teachers were supported to conduct mid-implementation science talks with youth to better understand ways that youth's funds of knowledge(s) (Moll et al., 2005) and repertoires of practice(s) (Gutiérrez & Rogoff, 2003) could be leveraged in their work during the unit.	This helped to understand specific views of meaningful science learning youth describe in their classrooms. Preservice teachers wanted to help support the youth in this work through their views and perspectives of science, so they implemented science talks with a sub-set of youth to help understand how these views can shape their practice(s).

Data Analysis

In this study, I used constant comparative analysis (Strauss & Corbin, 1990) and data reduction strategies (Miles & Huberman, 1994) to find themes related to 1) how PSTs enacted their views of youth-centered, equity-oriented science teaching practice(s) and 2) how local contentious practice(s) shaped their enactments.

I first began by open coding the final one-hour teacher interview where each teacher described their views of equitable science teaching and ways that their practice(s) were shaped by classroom practice(s), teacher supports and views of how they saw their youth learning the content/practice(s) of science and engineering during the implementation. Codes that emerged included: high points in teaching, low points in teaching, support/lack of support for a classroom community, student recognition, student expertise in STEM, advantages of preplanning, disadvantages of preplanning, advantages of debriefing, disadvantages of debriefing, views of equity, views of youth-centered, work, views of equity-centered work, methods course supports, mentor-teacher relationships.

After I coded the initial interview I started to build coding trees between them, including: views of science teaching (high points, low points and supports in methods courses), views of classroom communities, views of youth, views of equity-oriented practice(s), views of youth-centered practice(s), and teacher-mentee relationships. These coding trees then supported me in analyzing pre-planning and debriefs for relationships among supports and lack of supports these provided, views of science teaching allowed me to see how local practice(s) shaped these views of high points and low points, and then together with how the teacher-mentee relationships along with how these function within the classroom practice(s) helped me see how the PSTs viewed youth and support for youth.

Ultimately, I wanted to understand how did their planned youth-centered, equity-oriented teaching practice(s) function within the local practice(s) of their classrooms and were the tensions involved (either in support of youth, teacher-mentee relationships and support of their work during enactment) that shaped these practice(s). Finally, my last stage of coding involved understanding tensions in local contentious practice(s) (of the classroom) between PSTs views of enacting youth-centered, equity-oriented science teaching practice(s) and the broader classroom community spaces they were in.

Findings

In this section, I will discuss the findings for this study. Findings indicate that 1) PSTs took different approaches to implementing youth-centered, equity-oriented science teaching practice(s) based on local contentious practice 2) these tensions in local contentious practice forged opportunities to imagine or enact ways shape/reshape ways to support meaningful science learning for and with youth in their classrooms. I will begin by describing each PSTs, their view of their classroom communities and their role in them, ways they view youth-centered equity-oriented science teaching and types of enactments of these practice(s) with examples from their work in the classrooms. Lastly, I then will delve into each case to understand how local contentious practice were shaped by the institutionalized struggles in the classroom —and how these shaped teachers' view and purposes of science teaching.

Carol

Carol (Figure 5.1) is a 21-year-old, white female from rural, mid-Michigan. At the time of the study she was completing her senior year at MRU. Her major is elementary education with a focus on English Language Arts and a minor in TESOL (Teaching English to Students of Other Languages).

Figure 5.1: Carol with one of her student's electric art cards that was gifted to her after the engineering unit.

At MRU, she began her degree in Kinesiology which provided her with many opportunities to learn science. However, in her life experiences, she noted that she has worked with children in many capacities. She has coached soccer, taught swimming lessons, and has also been a Sunday teacher of the "we believers" (youngest children) program at her local church. In her biography she discussed: "I never questioned becoming a teacher, until I noticed that I worked extensively in education [and in support of youth] so I changed my major" (Biography, Carol). In terms of viewing equity in her postsecondary education, Carol discusses:

> I grew up in a rural white town near MRU and the idea of culture and race was never exposed to me, and that is something in my future teaching I want to make sure I incorporate. I learned about MLK day at school, but nothing else about other cultures or races …At MRU, they include a lot of teachings regarding culture and race and not having a diverse background, with this education, made me open my eyes to see that it is an important aspect to teaching all kids (Biography, Carol).

Carol's history-in-person acknowledges that her race and middle-class upbringing affords her privileges that the youth she has worked with at Liberty do not have, however, she does acknowledge that she has limited to no exposure to race and wishes to learn more about how to incorporate that in her teaching work. Furthermore, she seeks pedagogical experiences that will help her develop decision-making processes and learning from those processes in support of youth learning. In her biographical discussion, she discussed how in her teacher education at MRU there is heavy emphasis on teachers to learn from—and with youth—in the Great Lakes City community. This greatly shaped her own views of teaching historically over time because of how she hopes to learn about these critical connections (Field Notes).

Ms. C's classroom and Carol's connections to institutionalized struggles. Carol completed her field teaching for TE 400 in Ms. C's classroom. Ms. C is a new first-year 6th grade teacher who also graduated from MRU's teacher education program in Elementary Education the year prior to this study. Interestingly, Ms. C also did her field teaching experience at Liberty Spanish Immersion with the same youth that she taught the year of this implementation. At the time they were in 5th grade Spanish Immersion. Experiencing two years teaching the same group of youth at Liberty afforded her knowledge(s) of supporting the classroom community in expansive ways. These experiences provided important institutionalized expansive practices, which Carol through working on imagining her own views of science teaching, thought she could learn from.

Carol's work in TE 400 included over 20 hours of field experiences (social studies methods also ran concurrently with science methods which afforded an additional 20 hours in the classroom). Now in Spring 2018, during the EDU, she was working 3-5 hours a week during the implementation separate from her 40 hours of observations for her mathematics and literacy methods courses. Although this experience offered her substantive time in the classroom, in relation to the other PSTs in the study, Carol did not work too closely with Ms. C to develop her enactments as practice. Rather, Ms. C positioned Carol to learn from Ms. C as her mentor teacher and to model the instructional practice(s) she engaged with her students. These were critical to Carol as it led to tensions in not allowing her to shape/re-shape her own practices in relation to the science teaching she hoped to do during the EDU.

Ms. C's classroom. The classroom community, as institutionalized by Ms. C, was primarily driven by Spanish Immersion. According to Carol, Ms. C held meetings every Friday called "kudo meetings." These meetings attempted to create a classroom culture where youth chose a "spokesperson-or people" from their classmates each week. These "spokespeople" would then choose who to give "kudos" to in their class. This prompted youth to recognize each other for their work in the classroom. Carol noticed through her observations over many weeks viewing the kudo meetings that the culture in the class led to youth mostly supporting other youth who they had a rapport with in class. She also further unpacked how those that participated in Spanish Immersion would repetitively become leaders of the Kudo meetings every week. Because of this, Carol noticed tensions between how she initially viewed the student culture and that which the culture reproduced because at the end, those students who practiced more Spanish immersion were getting more recognized in the classroom (Final Interview, Carol).

Noticing these disparities between the institutionalized struggles of the classroom culture and how the youth felt welcomed and supported created critical opportunities for Carol to want to become engaged in the classroom community. She discussed that youth who were "labeled" as special education, did not receive the same supports and recognition during kudo meetings. Carol discussed: "There's three boys that I work with all the time [in the classroom]. They are special education students. I work with them mostly during tight situations, and when I see that she changes her tone or things with them, then I go and ask them what they need." (Carol, Final Interview). In this example, Carol viewed how Ms. C changed her teaching practices including her tone, that may have limited engagement from students with disabilities in her classroom. Over time, these pressures became evident through Carol unpacking Ms. C's work as a teacher. She noticed that Ms. C, even though she has little less than two years' experience with these same students, as a first-year teacher, did not develop important ways to leverage and recognize the multiple ways youth learn in the classroom. And furthermore, that her practices in the classroom could cause youth to feel excluded or not part of the broader classroom culture (Final Artifact Interview, Carol). Through this end, Carol discussed: "I think patience is a big one because in a way I feel like I've developed an understanding that you have to give kids time to work together and learn from each other. At the beginning of the year, you're not going to get the culture right at the beginning" (Final Interview, Carol). In one of our pre-planning meetings, Carol discussed that: "[Ms. C] has an experience a lot of us would want…. I wish I could teach the same group of kids twice, this opens up so many ways to be able to create a kid-centered classroom culture" (Pre-Planning Week 3, Carol).

Furthermore, Carol noted that when Ms. C's teaching pressures became evident to the youth in the class this created tensions between Ms. C and her students. She noted: "tone of voice, rolling eyes, small indicators of lack of connection, could make kids not feel welcomed in a classroom" (Final Interview, Carol). These tensions in unpacking how youth know and feel recognized or not by their teachers, prompted Carol to overcome her feelings about the broader classroom culture in Ms. C's class. She discussed: "I can't be upset …with Ms. C…but we have to develop this understanding [of support] with each other. Between teacher and student, student and student, and it takes a lot of time, but in the end, it will work…with what I learn here I will make it work for me" (Carol, Final Interview).

Carol's participation in Ms. C's classroom. Carol's role in Ms. C's classroom was different than the other two PSTs in this study. Carol's history-in-person is evident in her limited abilities to speak Spanish and how this inability tension with her mentor teacher's institutionalized pressure to focus Carol's teaching on Spanish Immersion. Before the engineering unit implementation, the pressure to teach in Spanish was not a problem because of the limited science time that Carol was afforded as part of her classroom observations. However, during the EDU, Carol's role as a mentor to the youth put her in a position where her identities and ways of knowing and being, including having limitations to speak Spanish, came into that science classroom.

One of the pressures of having Carol in the class and not being able to support Ms. C in the Spanish Immersion instruction created tensions between the pressures of Ms. C having to teach the unit in Spanish and her as her mentor teaching. These tensions created limitations in Carol to develop approximations of practice through the unit as giving Carol instructional time meant that there would be limited time for Spanish Immersion. Secondly, the mentoring support that Ms. C provided to Carol, became strained because Carol was not able to teach in Spanish and couldn't understand Spanish instructional practices.

Ms. C being a first-year teacher and the only 6th grade Spanish Immersion teacher at Liberty meant she was continuously observed by school administration. In addition, due to Liberty's positioning as one of the only elementary Spanish Immersion programs in the district and that was the student's last year before transitioning to middle school, Ms. C had to answer to parents and other community stakeholders regarding the proficiency levels of the youth in the Spanish Immersion class. Because of this. Carol's own history-in-person as a developing PST merged with the institutionalized struggles Ms. C had through her own pressures as a first-year teacher.

In addition to these structural influences on the culture of the classroom, the pressures on Ms. C prompted her to re-purpose much of the EDU in order to focus the work on Spanish Immersion rather than the critical uptake of engineering design for sustainable communities. For example, Ms. C purchased a Spanish unit on energy and electricity online which was not aligned with the goals of the unit regarding working through problems in the community and engineering solutions to solve them, a main focus of the EDU. Rather, these worksheets added extra components to the unit that limited the uptake of youth knowledge(s) and practice(s) in science, and it also created tensions for Carol in her planning to work with students. Because of this choice of Ms. C to focus on Spanish Immersion entirely through the unit, it became nearly impossible for Carol to co-plan her enactments with Ms. C creating strains in their mentoring relationship.

Based on this, Carol discussed not being able to plan with Ms. C and enact whole-group discussions as a low point in her teaching experience "we [Christina and Carol] planned on me teaching once a week, me basically taking control of the lesson which I was so happy about, but instead, I wasn't able to do that, because of the Spanish barrier. I know zero Spanish, maybe a couple of words, but not enough to teach a whole lesson in Spanish and them actually learning the content" (Final Interview, Carol). Here Carol discussed two points, the first is that at the beginning, Ms. C and I had agreed that Carol would teach her lessons to support approximations of practice(s) in the science course, but over time, this support was not followed-through. Carol's history-in-person as a limited Spanish speaker, were put against the needs of Ms. C. Throughout the course of the implementation, Carol positioned herself to teach part or some of the material in the engineering unit. However, once Carol entered the classroom, Ms. C reminded her of her inability to speak Spanish. Over time, and due to the frequency of these tensions between the institutionalized practices and the learning Carol wanted to get out of her preservice education experience, Carol talked to Ms. C about her needs as a mentee in her classroom. However, the response was that Ms. C could not sacrifice individual students to engage with Carol at the expense of putting them back on their Spanish Immersion. Here, Carol's views and purposes of science from a youth-centered lens were reshaped by local contentious practice to meet the needs of Ms. C's instruction (Field Notes).

Because of this, Carol's role after the third week of the implementation transitioned into supporting youth individually or in groups during project time. Carol stated:

> My mentor teacher didn't want me to do it in English, so I was kinda stuck…being in the background helping youth just on their own. I worked with groups that needed help. Sometimes that didn't work because I was speaking too much English…at first, she was more lenient, but towards the end [it was hard to support] the kids anymore (Final Interview, Carol).

Even though Carol's belief that Ms. C's view of her inability to speak Spanish as a limitation, Carol believes the youth changed their views about her as she worked with the EDU: "they saw me more as a helper before [when I did my student teaching] now during engineering, they see me more as a resource. Because before, I kind of knew what was going on, but not enough to give directions…but for engineering, I was able to give more definitive answers" (Final Interview, Carol). This speaks to the importance of PSTs being viewed as one type of expert in their mentor teacher's classrooms.

Carol's view of YCEO practices and how these shaped enactments within institutionalized struggles of Ms. C's classroom. During TE 400, the PSTs who participated in this study worked towards imagining their views of YCEO practice(s) (see Chapter 4). The analysis showed that the imagined practice(s) they imagined on enacting included: *(1) exploring youth and community science knowledge(s)/practice(s) (s) to create classroom spaces that enact youth views and purposes of science and (2) creating classroom communities by planning to relate with youth and enact to relate youth with each other.* Carol's (and the rest of the PSTs view of youth-centered, equity-oriented science teaching practice(s) specific to the ways they viewed the culture of science in their classroom communities. In her final interview, Carol discussed her view of equity:

> giving [youth] a chance to take reigns on something, because you may give the class all the same project, but some people will feel like they could do it and others won't" (Final Interview, Carol). She continues to discuss "some student might have a deficit in this, or they're struggle with this. Where if you give them a broad topic or something that they get to choose what they do with their strengths, then they have reigns on it and become passionate about it, which is something I love" (Final Interview, Carol).

Here, for Carol, her view of equity as a developing teacher is that youth see their purposes and views within the content they are learning, but also that the content engages with students' strengths and to take reigns on it in passionate ways to support youth learning (Final Interview, Carol).

Focusing on youth through differentiation. During the unit implementation, and because of the limited opportunities to enact practice(s) in the classroom, Carol instead focused her attention on youth who she noticed through her work on YCEO practices that were not being supported by the broader classroom culture. Andy, who was a student with disabilities and had a very strict Individualized Education Plan (IEP), worked extensively with Carol during the implementation. In her pre—post planning meetings she discussed how she focused her methods course work and the classroom communities' assignments on doing the most she could to take up Andy's funds of knowledge(s) in science and other methods courses (Field Notes).

Through these experiences, Carol learned that Andy's uncle was an electrician and during the implementation, seeing that Andy was not participating much in the classroom community, she leveraged this expertise extensively to support him in Ms. C's classroom. In one of her pre-planning meetings, Carol discussed:

> I want to go with Andy big time. I know he's a special education student, so knowing that background information helped me better understand him…Ms. C is rough on him and I pay more attention to him because of that as well…sometimes I wasn't able to help him, but he surprised me big time with what he was able to do in ways that others couldn't (Pre-planning Meeting, Week 3).

In this excerpt, Carol showed that not only does she want Andy to be successful despite not being recognized and having a "rough time" with Ms. C, but she also wanted to show Ms. C (and

Andy's classmates) that he could do science, and that his methods to achieve that science could be different than the direct instruction Ms. C provided to her students (Field Notes). Carol also connected to Andy's expertise in electricity in how he has seen his uncle do his electrician work: "there's a couple of times when he understood how electricity flow worked…he just dove right into it… it must be that his uncle showed him through his work as an electrician" (Final Interview, Carol). In her final interview, I followed up with Carol about the ways she wanted to challenge Ms. C's view of Andy in her class. She discussed:

> When [Andy] got pulled out for special education, he had very limited engagement in science class. That is why I was so focused on him, because he didn't do enough science in class like the rest of the kids. But one of those times he came back in the middle of the electric card unit, and he made his card work perfectly in no time. While all the other youth struggled… and Ms. C worked hard to get them focused… he got it to work… all the kids even struggled to make those switches with the tape and his card was easy... it said don't touch it if you don't want to turn it on... It was an amazing teaching moment for me because he hates school, but he had fun working with me to make the card light up… and Ms. C saw that I was able to help him be successful in this lesson" (Final Interview, Carol).

Working with Andy and unpacking his work in the class, helped Carol to develop a view of enacting equitable practices which became part of her repertoire of learning to teach from the institutionalized struggles she experienced in Ms. C's class. She called this view of equity, differentiation. In this she stated, "for me equity now means differentiation, making sure that it is addressed all the time when I'm thinking of a lesson, like we're doing now in literacy and math methods, but I don't think I would have understood how important this view was if I didn't see it with this curriculum. I will make sure that I influence differentiation in my future lessons" (Final Interview, Carol).

With this understanding of differentiation, she also sought to shift her classroom teaching practice(s) because she saw that the culture of the classroom was dependent on who was participating most in the culture of Spanish Immersion. She stated "I'm a big fan of group work and pair work because, me, I was quiet in the classroom. I never raised my hand. Giving youth a voice when they're not talking is important, but when a kid is quiet, chances are they are thinking… we need to be able to involve those kids too" (Final Interview, Carol).

Centering youth views of community on engineering design. In another type of teaching enactment, Carol found ways to merge her limited opportunities to teach science with supporting youth groups whose problems in their engineering designs were addressing the classroom culture she had seen through her observational experiences. One group, which worked on the Pared de Kudos (Kudo Wall) wanted to publicly display the frequency of youth getting kudos during the kudo meetings. Carol felt passionate about addressing this problem space because not only was she observing the classroom community in this way, she also noticed that Ms. C's teaching practices in the class prompted youth to also focus on addressing this problem. The design used a hand-crank powered generator that when kudos were announced, would be cranked, and the lights around the wall would light up. Not only would this design support a classroom culture of sharing kudos in a celebratory manner, it also publicly displayed who received kudos and seeing patterns over time of repetitive kudo-giving which the youth at times, complained about with each other. In Figure 5.2, Carol is working with Gina, one of the youth who worked on the Kudo Wall in connecting electric tape and LED lights to light up the Kudo Wall in the classroom. The picture in 5.2 was taken after Carol felt comfortable enough with the youth's understanding of connecting the copper tape and LED lights around the board, so that they could test the design to light it up.

Figure 5.2: Carol working with Gina to turn on the Kudo Wall.

Carol and local contentious practice in Ms. C's classroom. Holland and Lave (2009) discuss how "local practices come about in the encounters between people and as they address and respond to each other while enacting cultural activities under conditions of political-economic and cultural-historical conjecture" (p. 3). Carol's experiences in Ms. C's class, how she was positioned and eventually what she did to support youth was driven by these local contentious practice(s) she developed. These practices helped support a view of equitable science teaching within the institutionalized struggles of Ms. C's Classroom. Figure 5.3 shows a summary of how these interacted in her case.

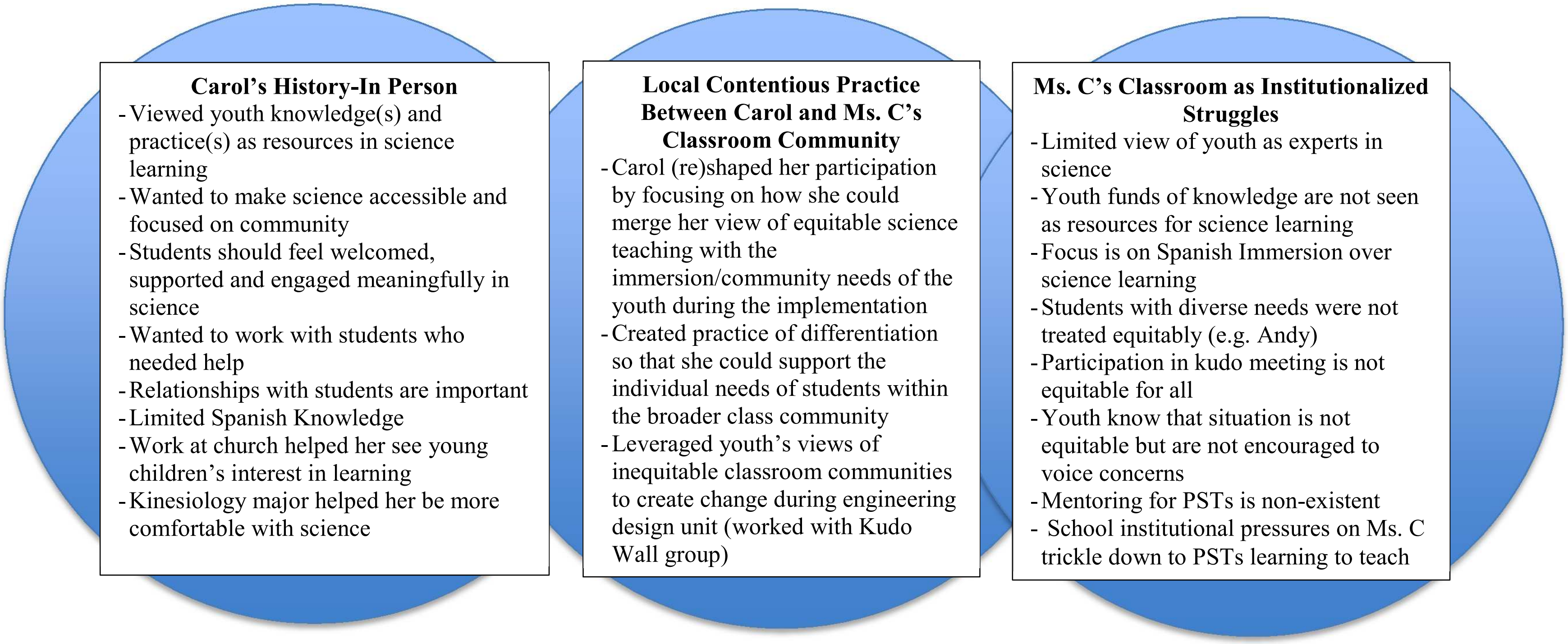

Figure 5.3: Relations between Carol's history in person, institutionalized struggles and local contentious practice.

Overall, Carol (re)shaped practice(s) to support youth meaningfully around tensions that arose between her views of science teaching and her history-in-person and the institutionalized struggles in Ms. C's class. Although she could not fully engage in the Spanish Immersion classroom by learning to teach and enacting her views of YCEO practices, Carol felt she supported youth in the uptake of their funds of knowledge(s)/repertoires of practice(s) that the EDU called for in the best ways she could by challenging Ms. C's explicit focus on Spanish immersion. These productive challenges helped to sustain Carol's learning to teach in ways that centered youth and not her own needs as a developing teacher. For example, by helping the Kudo Wall group, youth' views of the classroom community were upheld in the same ways that she felt tension in the analysis of the relationalities in her classroom community. This was a form of supporting local contentious practice.

Also, with working with Andy, she also upheld her knowledge(s) of his view of science through his experiences with his uncle so that he could design a card that was not what others in the class were designing. She did this by leveraging the ways the mentor teacher rewarded science participation through immersion and class contact time. Ms. C assumed Andy did not know how to do the card because he wasn't receiving science/engineering instruction at the same times and days as the other youth. Carol took advantage of this and worked more and more with Andy to design a card he wanted and to also challenge Ms. C's normative views that youth only learn through direct instruction/contact with the teacher. Here Carol challenged the classroom community by questioning what is a legitimate resource for science learning. Carol showed that Andy's knowledge of his uncle's electricity practice is one of these.

Sophia

Sophia is 22-year old white, middle class female from mid-Michigan (Figure 5.4). She is majoring in Elementary Education with a teachable minor in TESOL at MRU. She's also part of the Global Educators Cohort Program (GECP) and has been involved in coaching and after-school instruction in her local community schools. In learning through the GECP program, Sophia notes that there is a heavy emphasis on inclusion of people from racially diverse and ethnic groups (Biography, Sophia). She is able to focus unpacking these issues of race and diversity in her MRU courses, however interesting to her, she feels learning about these are "outside of her comfort zone." (Biography, Sophia). She notes, "I am a white middle class Christian female who speaks only one language. I am privileged, and I know I am privileged, but I am trying to understand that and see things from other people's points of view." (Final Interview, Sophia). Furthermore, in her TESOL work, she has had a variety of placements where she has been challenged out of her comfort zone regarding seeing the interplay of privilege and her own history-in-person. She discussed: "I had a TESOL placement in a school district near my university where I was placed with the teacher who was the director of the TESOL program…she as in the same boat as me in not being diverse, and it was nice to see someone who looked like me, being able to teach kids who are different… I aspire to be in that position someday" (Biography, Sophia). Important in Sophia's views of science teaching is that she recognizes power and privilege and knows that her race affords her privileges others don't have, however, she is still seeking to understand how to unpack this understanding in her own teaching (Final Interview, Sophia).

Figure 5.4: Sophia teaching about community ethnography.

Ms. L's classroom and Sophia's connections to institutionalized struggles. Ms. L has over 25 years of experience teaching elementary school in mid-Michigan. Immediately upon being placed with Ms. L, Sophia noticed how meaningful their connection would be. She noted: "I think we have a good relationship. We're usually pretty much always on the same page about things, not only about school but our personal lives too… we have gotten to know each other at that level" (Final Interview, Sophia). Out of the three PSTs in this study, Sophia noted having the most support and the strongest connection to her mentor teacher. Taking this view, tensions between Sophia's view of equity-oriented teaching, and institutionalized struggles were present, but not as critical and transformative to her practice in comparison to the other two PSTs.

Before working on the EDU, Sophia's presence in Ms. L's classroom was driven by needs in her methods course assignments. She had very limited opportunities to see science instruction, and much of her learning on classroom communities was driven by individual interactions with the youth in her class (Field Notes). When the engineering unit started, Ms. L, being the senior teacher of the three mentor teachers at Liberty, had many questions about teaching the unit. She felt unsure about how to support youth in the classroom with the content knowledge that the unit called for. Ms. L discussed with me before starting the unit, how she has never done a unit that centers community iteratively through the design and that was "hands-off" in terms of giving more individual or group time to the students (Field Notes). This prompted Ms. L to re-organize her views of teaching in support of enacting the EDU.

One of the institutionalized struggles associated with Ms. L's enactment in the EDU—which was related to her tension in teaching a unit that called for iterative unpacking of youth knowledge(s) and practice(s) as part of the design—was that she requested additional supports. She wanted someone to be in the classroom with her supporting the youth in their engineering work. When Dr. C offered the opportunity to merge the EDU with PSTs teacher learning, Ms. L was happy to learn Sophia was going to spend more time in her classroom (Field Notes).

***Positioning as an expert teacher*.** From the beginning of the enactment, Sophia was already positioned by Ms. L as an expert teacher in engineering. Before the engineering unit, Sophia's interaction with youth in Ms. L's classroom was highly individualized. Sophia noted that upon entering the classroom after the start on the engineering unit the first day, Ms L immediately positioned her as an expert teacher. She noted "before doing the [EDU], I don't even think the kids knew who I was, but after I started working with Ms L. on the engineering project, all of a sudden I was this knowledgeable engineering person" (Final Interview, Sophia). However, Sophia did not see herself as an expert in the engineering content called for in the curriculum "when I came in [Ms. L] was like I do not know anything about this. She's like this is my first experience teaching this kind of stuff. I never really learned any of it…she told me she came to an MSU workshop and they taught her how to work through the stuff, but she was not comfortable teaching it" (Final Interview, Sophia). Furthermore, Sophia discussed that Ms. L with being open with Sophia about her apprehension to teach the unit led to her being more open to working with Sophia as a co-teaching, because according to Sophia, with the EDU, Ms. L's years of experience did not matter, but that she was willing to learn alongside her mentee. She noted:

> She was very open about the fact that she wasn't an expert on the topic and she was open to ask for help… I think that is an expert teacher move because it shows that even if she has been teaching since 82, there are still things that she can learn…by saying I have my co-teacher here…she is showing that a good teacher is also a good learner (Final Interview, Sophia).

However, Sophia viewed this positioning as problematic. It created a tension in her developing teaching practices and her history-in-person alongside the institutionalized struggles of working in Ms. L's class as a co-teacher. She noted: "I am not that cocky teacher…I am happy Ms. L let me be seen this way by the kids, but I also did not have a lot of experience in engineering for me to be that expert teacher she told the kids I was" (Final Interview, Sophia). Furthermore, she noted:

> My experience with the EDU is when I learned about it in TE 400 last semester with the templates that we did in class… I experienced learning how the students would…[inaudible 00:16:58] this helped me, but I don't see myself as an expert teacher… because of how much co-teaching Ms. L was expecting me to do, I was reading the binder all the time (Final Interview, Sophia).

Working in Ms. L's class for Sophia provided her first-hand experience to be viewed as an expert teacher by a highly experienced teacher. Although the expertise she was recognized for was content-based and not based on supporting youth in equity-oriented ways, Sophia leveraged her power as a co-teacher to support the kinds of youth-centered practices she believed were important to her enactments.

Sophia's view of youth-centered, equity-oriented science teaching practices and how these shaped enactments within institutionalized struggles of Ms. L's classroom. Along with the other PSTs in this study, Sophia also developed youth-centered, equity-oriented imaginaries through TE 400. She noted in her work in TE 400, how important it was to unpack classroom communities in relation to how students feel welcomed in the classroom (Field Notes). However, Sophia felt that she could not be a good equity-oriented teacher. She felt that because she lacked experience teaching culturally diverse youth, she needed more opportunities to shape what she meant by equity-oriented teaching (Field Notes). She does view her work developing youth-centered practices which she views as student centered. She noted "I think [youth-centered] would be making sure that students are the center of attention in the class, so you don't want to be like…I think that's something important and not tell them why" (Final Interview, Sophia). Furthermore, she unpacked how she would engage students in being the center of attention: "In my classroom…the center of attention would be like having groups and I float around to them and I'm like what do you want to do, not this is what you are going to do" (Final Interview, Sophia). In her history-in-person view of teaching, Sophia's conceptualization of youth-centered practices is focused on youth driving learning. She pushes back on her own power as a teacher in the practice she imagines enacting by saying she will not tell youth what to do.

Lesson on community ethnography. During one of her co-teaching experiences, Sophia planned to teach a lesson on analyzing the community ethnography data the youth collected from other youth in their school about community problems (Teacher Field Notes, Sophia). I worked with Sophia on developing a lesson and activity in helping students critically unpack their learning from the data in terms of adults, students and Great Lakes City members about community problems at the school. Sophia planned her lesson around the assumption that students knew how to read graphs and extract information from them (De-brief, Week 4). In this experience, Ms. L was supporting Sophia in teaching her own lesson. It was also her first time where she taught on her own without being positioned as a co-teacher in the classroom (Field Notes). During the lesson, Sophia presented various PowerPoint slides with information from the survey and asked students to examine the data. She did not want to tell the students what the data said, but rather have them analyze and draw conclusions from it.

It was evident that she suffered tensions in this lesson regarding her view of youth-centered practices. In her post-planning debrief, she noted that she incorrectly assumed youth knew how to analyze data, and so this created an institutionalized struggle to re-shape her teaching in the moment. She noted that “groups in the back were not interested in the lesson and were talking a lot and were not very engaged and this took away from me centering the lesson” (Final Interview, Sophia). When Ms. L noticed that the youth were not paying attention and disengaging, she immediately began to speak up and re-center the co-teaching role that she had with Sophia during the EDU experience (Field Notes). However, it was evident that Sophia wanted to keep teaching on her own during the lesson. After Ms. L intervened, Sophia thanked her in front of the class for her input and re-treated to figuring out a way to change the physical space in the class as a way to increase discussion (Field Notes, Enactment Week 4).

Because the youth did not have the knowledge and tools to unpack the graphs on their own, Sophia could not create groups and work with them all at the same time. She also did not want this practice to re-center Ms. L as a co-instructor (De-brief, Enactment Week 4). She then decided to move the desks and the cart that usually sits in the middle of the classroom. Where the cart sits, lies is a rug, and she asked all the students to sit in the rug (Field Notes). After she did this, Sophia noticed students sat with their friends prompting more discussion. By supporting students to sit with whom they felt they could discuss the learning with, supported her to have greater control of the discussion in the classroom (Field Notes). These rich discussions then re-centered her teaching in that lesson (Teacher Talk, Sophia). She noted “kids were discussing again... there was one suggestion of a basketball hoop with a recycling bin on it as a design to help with recycling materials, they all started talking about making recycling more fun… they were thinking of ideas…I now could talk about how to merge community problems with what they saw in the graphs” (Teacher Field Notes, Sophia).

In her reflection of this teaching experience, she noted: “I realized that there are certain things that can go wrong when you are teaching, and you have to be prepared for that…I thought students would have more experience in analyzing graphs, and I assumed that when I planned for this lesson…but I also wanted to do right by the kids” (Final Interview, Sophia). Here, Sophia was critical of her own preparation and her teaching which significantly impacted her history-in-person as a developing teacher. She metacognitively examined how she had to be aware of her own views of her students with teaching and do right by their learning.

Sophia and local contentious practice in Ms. L’s classroom. Sophia’s work in Ms. L’s classroom was greatly influenced by how she was positioned by Ms. L as an expert engineering teacher. Although Sophia did not feel comfortable being recognized as an expert teacher by Ms. L, this positionality greatly influenced her history-in-person within the broader classroom culture. Sophia was excited that this recognition afforded her greater opportunities to work with the youth in the classroom. However, tensions between the history of institutionalized struggles in the classroom community were not about supporting equitable science teaching from her view as a PST learning to teach, rather, her contentious practice became about upholding Ms. L positioning of her as an expert engineering teacher. Furthermore, this is an interesting finding as one would believe that the more approximations of practice, the greater opportunities for teacher learning. However, this positioning forced Sophia to improve her practices at a faster rate, possibly missing on important opportunities to unpack views of inequities, or even relationalities in within the classroom community.

The local contentious practice between these institutionalized struggles and Sophia's history-in-person view of her developing teaching practices forced her to change teacher learning to become more knowledgeable about the pedagogical content of engineering design. In supporting these practices, Sophia worked arduously to learn as much as she could from the EDU materials, oftentimes teaching herself how to engage in the scientific practices as if she were the student. She also worked with me several times to review the materials after the end of the school day to make sure she knew what to give the youth during their lesson. Ms. L's dependence on Sophia's expertise was also a struggle for her because she always had to be "on her feet" in the moment to answer questions for Ms. L or for the youth, as Sophia was positioned to co-teach with her during each enactment.

When having the opportunity to teach by herself though, Sophia took advantage of this to enact practices that she viewed were youth-centered. When discussing learning about equity, Sophia mentioned that she was not comfortable discussing how her teaching was equity-oriented, because she feels she is still developing this learning in her practice (Field Notes). However, she views that as a teacher, she would enact this view of equity: "if your student has a bucket of knowledge it comes a little bit full already, they don't come to you empty kind of thing… I have to recognize that bucket" (Final Interview, Sophia). Figure 5.5. shows Sophia's history-in-person, institutionalized struggles in Ms. L's class and local contentious practice.

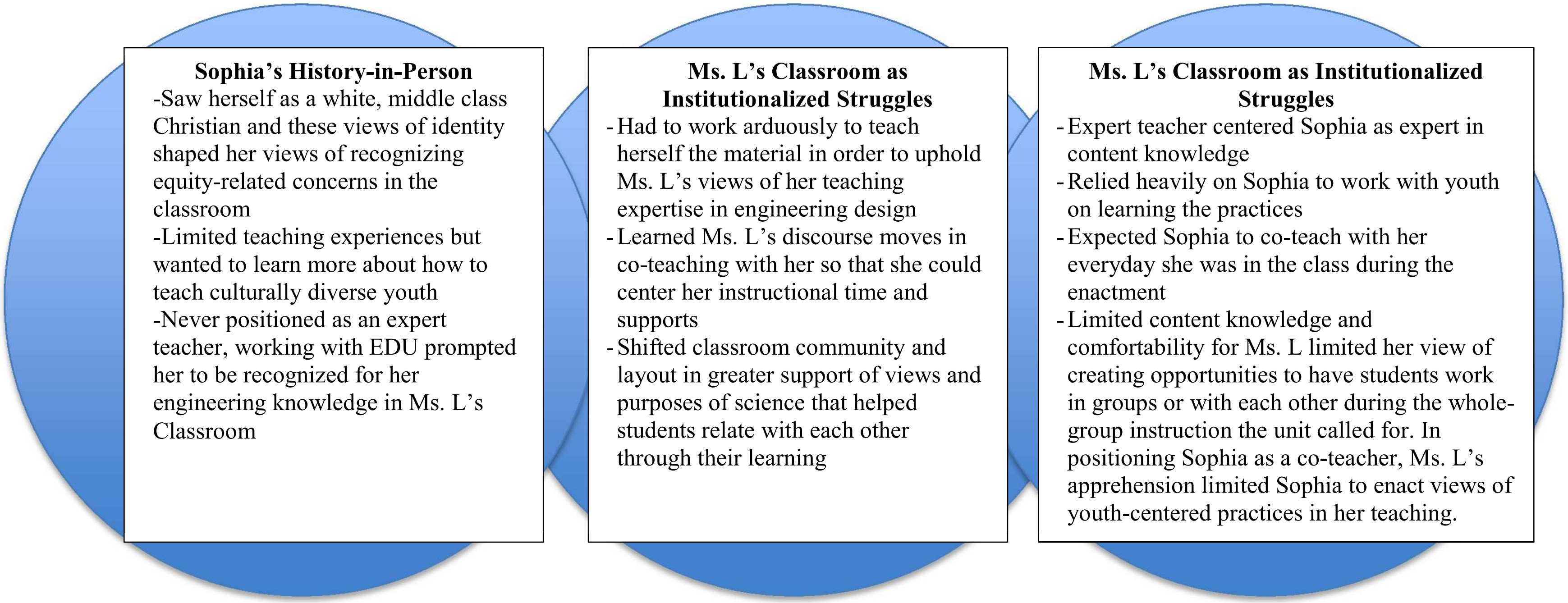

Figure 5.5: Relations between Sophia's history in person, institutionalized struggles and local contentious practice.

Maria

Maria, a 21-year-old white, middle class, female who grew up in west-Michigan. She is an Elementary Education major with a TESOL minor who describes herself as "deeply equity-focused." (Final Interview, Maria). Her goal is to teach in a linguistically-diverse school like Liberty where her youth are learning both English and Spanish. Maria has taken it upon herself to learn the Spanish language and most recently visited Spain for a summer semester the year before starting TE 400. Her visiting Spain was the beginning of her long road to understand its hegemonic and colonizing history (Field Notes). Her goal after learning Spanish fluently is to visit Latin American countries and unpack ways colonization has affected them economically, racially, linguistically and politically. Maria was also her class president and is heavily involved politically in causes for social justice (e.g. #MeToo movement, anti-Trump rallies) on MRU's campus and was also involved in many honor/societies at MRU. She discussed her view of education:

> I very strongly believe that education is the most powerful way to enact social change…and I believe there is a lot of social change that needs to happen in this country and in this world… not later but now and by educating and figuring out and helping them figure out power structures that exist and dismantling them together, we can push [youth] to be critical of what they learn in school…I am critical and I recognize that as a white woman who had a family that encourages me to be critical …being a teacher that recognizes that is important and invaluable [to recognize a type of education that some have and others don't because of privilege]…having a lifelong desire and passion for creating equality in the world through my teaching (Final Interview, Maria).

Through my work with Maria, I have come to realize that she was the most critical—in terms of understanding the role of race and racism in society—of the three PSTs in this study. I say this because she appeared to understand and sought to disrupt these hegemonic notions in her classroom and was critical of her own views of race and racism as a developing teacher. In her work as a teacher, she continuously found ways to support this critical unpacking, even though the structures of learning to teach in her classroom community did not allow her in doing the "radical teaching" she wanted (Field Notes). Maria also constantly tried to find ways to connect power and privilege in Ms. W's class to the broader goals of Liberty's Spanish Immersion program.

Maria's historicized views of inequities. Much of Maria's knowledge about power and inequities came from her discussions of the experiences viewing her father's work. As a city manager in her hometown, Maria's father was directly involved in government decisions that affected her community. Having access to government functions, this shaped much of her thinking around access to transportation, schools, community centers and programs in her West-Michigan hometown (Field Notes). Adding this knowledge to her experiences in Ms. W's class and participating in this work during the EDU enactments, she constantly sought to shape and re-shape experiences for her students through a lens of power and privilege. This view of power and privilege and how it historicized in her life through her experiences with her dad was critically important to Maria's history-in-person.

As part of her own learning to teach, Maria decided to take it upon herself to analyze power and privilege at Liberty through completing an undergraduate research project alongside her enactments experience. Maria noticed before even beginning the implementation that youth in the Spanish Immersion program were given opportunities and greater access to out-of-school resources than the youth in her 6th grade non-immersion class. She wanted to understand how capital (social and cultural) between the youth who were in the Spanish Immersion program and those that were not, were different and how did that shape their opportunities for learning.

Co-learning research relationship. One important note on Maria's participation in this study in relation to why she sought out these opportunities. Maria did not have a car, so she could not choose a schedule to enact her teaching at Liberty on her own time. Rather, she depended on me and my schedule because I drove her to school every day. Inevitably, during our car rides, we would have very critical, open conversations about the ways she viewed her other methods courses and her learning at Liberty. This also prompted Maria to discuss her life experiences with me through our co-learning relationship. Because of this, the relationship I had with Maria was strikingly different than the rest of the PSTs in this study. This allowed for us to examine more structural inequities and current events in society in our car rides which also significantly increased our face-to-face compared to other PSTs in the study. Although I viewed all teachers as experts and knowledgeable of the culture of their classroom communities, I felt that the lines of my work as a researcher were much more blurred with Maria because of the dialogic learning during our car rides—we shared our historicized views of power and privilege and how it shaped our views of teaching over time. This created a meaningful connection to examine Liberty through her undergraduate research project as well as critiquing her own views of race and racism. Because of these deep conversations during our car rides, I believe that Maria learned to critically engage in her own assumptions of race and racism based on her student teaching experiences and sought support from me and this research project to learn how to further unpack those questions in her teaching.

Ms. W's classroom and Maria's connections to institutionalized struggles. Ms. W's experience teaching goes back to her days teaching at a juvenile detention center. Much of Maria's view of Ms. W's classroom communities came from her understanding that Ms. W's job called for her developing a strict demeanor to manage youth's personalities in the prison (Field Notes). Maria discussed that Ms. W is first and foremost a classroom manager and views subject-area expertise and disciplinary engagement as an important second (Final Interview, Maria). According to Maria, Ms. W wants her students to function well in society. Through this, she emphasizes knowledge(s) of rules and norms as shaping youth into productive members in their communities. Although the Great Lakes City community is important in Ms. W's classroom, her view of community is not about leveraging resources, but rather, that students learn to participate in the already existing culture (of power) in their society. This has important implications along racial, class and gendered lines, as Maria from her history-in-person and positionality of unpacking power and privilege in her teaching, knows that opportunities are not the same for all students and that race is an important factor in how learning happens in the classroom (De-brief, Week 4). However, Maria does argue that Ms. W seeks change this view in her teaching. She discussed:

> Ms. W moves around, she's tried different things and taught different grades…I feel like I have a lot more to learn from her in a lot of ways beyond just like the [mentor/mentee role]…I am not talking just about her being a teacher and having a certificate to teach, but the experiences she has had… in the prison and in diverse contexts…that she brings to her teaching (Final Interview, Maria).

Maria's role in Ms. W's class. Maria's work with Ms. W as a mentee was fruitful, but Maria noted that Ms. W centered classroom and time management as a way to maintain classroom order. Maria discussed that during her observation time in the fall during TE 400, Ms. W limited Maria's teaching time because she wanted to make sure that both her PSTs mentees were receiving the same amount of contact time with her (as a mentor) and her students. These prompted multiple negotiations between Ms. W and her other PSTs colleague so that instructional needs of both PSTs were met, regardless of how involved or meaningful those experiences were for the youth in her classroom. Maria even noted that with the limited science time they had, the teacher only allowed them to teach if they worked together as co-teachers with her. Maria's institutional struggles to teach prompted her to leverage this view of co-teaching as a way to work closely with Ms. W. She used this to develop learning opportunities for the youth during the engineering unit implementation. Maria felt that this experience was the best she has had in her teacher education program because of how this forced her to be attuned to changing practice(s) over time (Field Notes). Maria discussed:

> This experience gave me much more real-life experiences of teaching because there were always adjustments being made at the very last minute…Ms. W and I had a curriculum we were going to teach… and I tried so hard to work with her… I wanted to support individual students, but circumstances made us change these at the last minute…and she was supportive in that…[before this experience] I saw that in my preservice program we don't teach a lot…we spend an entire semester building up to do this one lesson… and sometimes not even alone…which I feel is kinda silly…[with this implementation], I saw doing just one lesson is not realistic in teaching (Final Interview, Maria).

These constant adjustments that were produced were a result of tensions Ms. W had experienced in teaching the EDU. When Ms. W negotiated working with Maria during Week 1, Ms. W discussed with me that she didn't feel Maria was prepared to teach on her own. In her first teaching experience, Maria planned an entire lesson on teaching the engineering design cycle. During this lesson, Maria worked to connect the engineering design cycle to a previous lesson she did in TE 400 on connecting spaces in the community to relationships between living things. Here she leveraged the previous discussion she had with students around what parts of the community were important for living things to survive and feel protected (e.g. squirrels hiding in trees). She connected this lesson to the engineering design cycle by centering an engineering design as a place/thing that could help the community in the same ways that trees could help squirrels for protection.

All in all, she focused on how community problems were important to solve, and that engineering can be a way to solve them. (Enactment, Week 2). However, during the lesson, Ms. W's focus on management prompted her to constantly interrupt Maria's instruction (Enactment, Week 2). Students were not being attentive or were talking with each other. There were even times when Ms. W centered what was happening as way to mentor Maria through her instruction. She said things like, "see this is what you do when you see this happening" referring to how to center students who are disruptive in the class back to the lesson (Enactment, Week 2).

However, as the engineering lessons progressed, Ms. W was increasingly feeling that the unit was not allowing her to support these practices of control over her students. The lessons after teaching about sustainable communities were focused on construction, and here students in groups had to use materials in order to create designs. Oftentimes, these implementation days turned to panic and disorder, and discussion amongst groups as well as moving around in the class. This was a normal part of the design process. This caused tensions in Ms. W's practice(s) as a teacher because she had difficulty leveraging student's funds of knowledge(s) through the curriculum through a classroom community that was centered on movement and talk that was not centered around her control during instruction. After the end of Week 2, Ms. W began to seek help from Maria in helping her seek these connections that the curriculum called for (Field Notes).

By Week 5, because of Ms. W's increasing view of Maria as an expert teacher in her class (Professional Development, Week 5), Maria was teaching one or two lessons a week on her own. In addition, Ms. W saw that Maria's transportation limitations could be leveraged to support increasing her instructional time in the classroom as she began seeing her as a teaching expert through the EDU. Before Week 4, Ms. W asked Maria to do work with individual groups of youth, make copies, or seek materials from other teachers for the unit, but then seeing her connect with student's lives through group time during the engineering lessons, Ms. W moved to integrate engineering to other subject areas (Field Notes). Maria was at Liberty school for 15 hours per week between the engineering implementation and observations during her mathematics and literacy methods courses. More than any of the other PSTs in this study.

Maria's view of youth-centered, equity-oriented science teaching practices and how these shaped enactments within the institutionalized struggles of Ms. W's classroom. Because of Maria's view of power and privilege (based on how she criticized her own views of race and class during our car rides) in relation to her history-in-person and experiences in her home community, her views of equity were developing even before entering MRU to complete her education degree. As mentioned in Carol's discussion, Maria was also part of the TE400 course that developed imaginaries towards youth-centered, equity-oriented science teaching (see Chapter 4). However, Maria also had her own youth-centered, equity-oriented science views that she wished to enact as part of her work in Ms. W's class. First and foremost, she wanted to recognize systematic power structures that existed in classrooms and second, making engineering and science accessible to youth. Maria discussed:

> To me equity is recognizing that not every person has the same opportunity to be successful and exacting policies, procedures, techniques, plans to ensure that those people who have equal opportunities have the same opportunities as the privileged people in society or those in groups (Final Interview, Maria).

Maria argued that knowing youth very well was important especially in making sure equity was present in the classroom culture. Particularly because not all classrooms and schools provide equal opportunities to engage in learning. The way she did this was by doing teacher talks with students, which she learned as part of the science talk assignment in her TE 400 experience. Because she had more time to work with youth in Ms. W's class due to her transportation issues, she asked Ms. W to allow her to work with three or four students to unpack their views of science learning (Final Artifact Interview, Maria). This helped her better understand what types of learning the youth wanted in their science class. She stated: "I wanted to learn more about what the kids knew and wanted to know… I am glad I had more time to talk with them since I was in class more…I think this curriculum [EDU] gave [the youth] the opportunity to have a STEM educational experience they otherwise wouldn't have…the way schooling is done right now just doesn't let them see things from their point of view and I don't want to be complicit in that as a teacher" (Final Interview, Maria). Maria believed that doing social justice teaching in science (and math) is difficult, but that it took more on her part as a teacher to build those connections. She stated:

> science and math for social justice is difficult, but I think teaching them through engineering is important and they are capable of doing. Engineering needs to be a viable

> career path for them and despite that nobody in the families of any of the kids in my class went to college, supporting them in being capable to do this kind of science is important…but also knowing why it's important to them…I think reinforcing that throughout my teaching process, has helped me connect with kids about what their future might look like in a very different way…something they have not been able to do because opportunities are not provided to them not because of them (Final Interview, Maria).

In taking advantage of her increased time in the classroom and her continuous seeking of leveraging youth knowledge(s) and practice(s) in their science teaching, Ms. W asked Maria to design a lesson around writing an argumentative piece on sharing their engineering design experiences based on what tools and supports they leveraged during the unit. Here, Maria planned students to discuss problems of community, how they wanted to solve them and what tools and resources they leveraged (Field Notes). By doing this, she was able to connect the ways to connect experiences of youth to their science learning. It also centered the ways science is important to them and how they see themselves as capable of doing science, which she as a teacher could recognize.

Furthermore, she argued that "I learned from the writing experience that kids don't express themselves a lot…I think more of equity now in that their personalities and voices are heard, especially the quieter kids in the class. They need to have an opportunity to express their thoughts and feelings and I think for those youth who usually don't talk, being able to do designs that focus on what they want to see changed was a way to be equitable (Final Interview, Maria)." She began to tie ways youth identify and position themselves in their learning as important parts of the teaching process. These views were also connected to her views of how Ms. W centered a classroom culture on rules and procedures (Field Notes).

In another instance, during mathematics time, upon Maria's request, Ms. W supported youth connecting engineering learning to fractions. Here, the youth worked to do a class count of the engineering materials for their designs (e.g. LED lights, dividing up the rolls of copper tape into equal strips) and through learning about fractions, they separated the materials between the groups so that each would have an equal amount (Field Notes).

In these two examples, Maria purposefully implicated herself and Ms. W in upholding ways to continuously connect the engineering design unit to other learning experiences in school—building a type of instructional coherence. This learning helped shape her views of youth-centered, equity-oriented teaching for social justice in science and across subject areas (Field Notes).

Views on race in the classroom. As she continued to unpack the systematic struggles with Ms. W's institutionalized view of rules and procedures in the class, Maria began to see how the role of race and power were evident in her classroom. Maria noted that youth in her classroom community were majority Black and female. She noted that the Black youth came together to support each other when they felt that the two white students were not being supportive or welcoming. Because these tensions were implicit through Ms. W's classroom culture of control, Maria noted that Ms. W did not recognize that her focus on structure and order created tensions because youth weren't supported to express emotions or how these race relations affected them. Maria discussed:

> [Liberty] is on the lower end of the equity scale…but I feel Ms. W [is trying her best] to support Students of Color…for example, Sarah, is a Black female student, you would

> think that she was [not supported in the same ways as other youth] but she’s one of Ms. W’s favorite kids. She gets extra time to do what she wants, reads, does gym class on days she finishes her work quicker… other typical power structures follow because society reproduces them…but my experience in this classroom is that the kids together have tried to circumvent them (Final Interview, Maria).

During one of Maria’s teaching experiences, Kiara, a Black female student in the class had an altercation with another student when working on her Light of Accomplishment design. The Light of Accomplishment’s purpose was to center the needs of the youth in the class during whole group discussions. The youth who worked on this design felt that Ms. W did not stop to check on the student’s learning while she did direct instruction, so they designed a small LED board with a green and red light on it so that if there was a question, the red light would go on and the teacher would know she needed to go back and discuss that problem with her students.

In this particular lesson, Maria was working with Kiara on her design. In working with her, Maria noticed that Ms. W was problematizing a bullying situation that occurred online and outside of the classroom. Maria discussed “Kiara is a very popular girl in the class and because the class really likes her, she controls a lot of the culture of the classroom” (De-brief, Week 3). Furthermore, Maria discussed that Kiara and Ms. W have a “strange relationship” where they “tell each other what they feel about one another”, and that a lot of these tensions and interactions between Kiara and Ms. W intensify already existing tensions around the focus of classroom management in the classroom (Field Notes).

During this lesson, Maria was working with table partners to discuss ways that criteria and constraints of the design could be improved by asking community members about their supports. Although Maria was officially teaching the class, Ms. W and Kiara were discussing their tensions about this bullying situation during Maria's instructional time and this kept students off task (Field Notes). Maria felt that these tensions created some difficulties in centering the youth on the engineering design work at hand. Maria instead of letting Ms. W's interaction focus the attention of the class, as she has previously done and experienced, decided instead to keep teaching and call on Kiara. She did this to limit Ms. W's interaction with her and to center Kiara's experiences as expertise discussing community concerns of her Light of Accomplishment design. During instruction (Figure 5.6) this was the interaction:

> **Maria:** Kiara can you tell me who are some people you will interview about your Light of Accomplishment board?
>
> **Kiara:** Let me ask them [Christopher and Lia group partners] what they think? *She turns over and asks:* Christopher and Lia what do you think?
>
> **Ms. W:** Kiara they were asking you not them?
>
> **Maria:** Kiara can you tell Ms. W why you decided to ask Christopher and Mia for their opinion?
>
> **Kiara:** Because it's a group project they can answer too (Field Notes)

Here, Maria not only centered her attention on Kiara, but she also recognized Kiara's call for her partners to help her answer the question. Maria purposefully recognizes Kiara's decision to call on her partners and asks her to answer Ms. W's request instead of immediately returning to tension between the teacher and the student. In the following transcript, Maria discusses how Ms. W mentored her in noticing student actions during her instruction. Maria didn't notice them before, but upon learning from Ms. W., she began looking for opportunities to become increasingly critical in her practice regarding noticing student movement and how this shaped learning. She stated:

Ms. W notices things that I wouldn't notice. At one point, I was teaching a lesson where one student got up like 6 or 7 times to wipe their nose. When the lesson was over, I talked to Ms. W to get some feedback and she told me: "did you notice that student that got up like 6 or 7 times to wipe her nose. If I was teaching, she wouldn't do that…" To me it wasn't distracting to other kids because it wasn't taking away from their learning…if I see something like that again, I will make sure to center it around what the kids are doing…maybe I need to notice more (De-brief, Week 3).

Through the experience of noticing moments of tension in her instruction and also in how Ms. W prompts students to center classroom management, created in Maria opportunities to challenge institutionized struggles to in-the-moment shifts in instructional practice(s). Maria discussed with me how preservice teacher education lacks teaching future teachers how to make sense of realities of classroom practice(s).

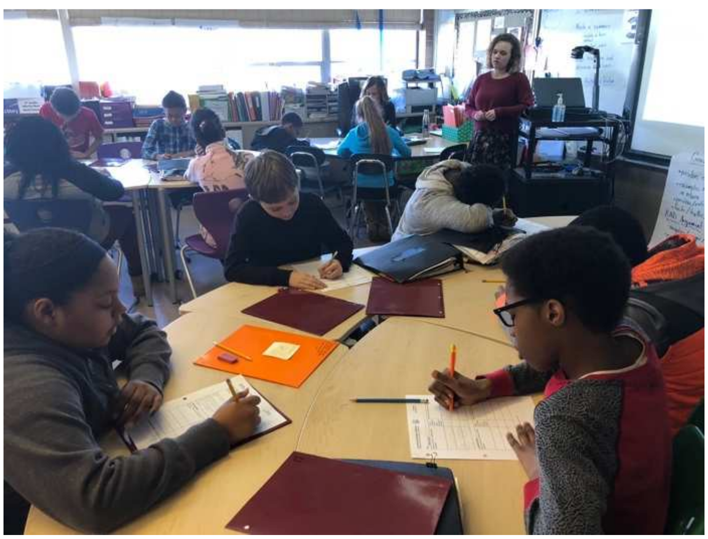

Figure 5.6: Maria teaching about criteria and constraints of design.

Maria and local contentious practice in Ms. W's classroom. Maria's experiences in Ms. W's class and local contentious practice(s) based on her instructional experiences can be seen in Figure 5.7. Overall, Maria's work in the classroom was heavily impacted by her increasing teaching time. By Maria having the opportunity to teach more than once or twice a week during the engineering unit, was able to impact the youth in many different ways. The first was through her productive shift towards youth-centered, equity-oriented practice(s). First, she began by individually upholding student's funds of knowledge(s) through individual interactions. Here she showed Ms. W ways that youth ways of knowing and being could be supported during the engineering unit by being recognized as an expert in leveraging youth funds of knowledge. This then gave Ms. W confidence in letting her teach more over the course of the implementation. Maria then leveraged this power to focus conversations in the class around leveraging youth' strengths. In addition to focusing on leveraging youth strengths, Maria learned the importance of moment-to-moment interactions and how these can become important sources for upholding youth's engagement in science learning.

Figure 5.7: Maria working with Sirous on his electric art card.

For example, Maria re-purposed Kiara's interaction with Ms. W which originally was meant to center the teacher as the classroom manager (by Ms. W revoicing Maria's question about asking Kiara directly about who in the community she would ask about her Light of Accomplishment design) to one where Maria re-centered Kiara's positioning to leverage the strengths of her classmates in this interaction. Here, Maria not only upheld Kiara's positioning, but she also recognized the importance of relationalities between students as a community of learners. This interaction helped to further position Maria as capable to teach on her own, one of the reasons why Ms. W increased her instructional time. Ms. W may have learned to center Kiara's positioning and views and purposes as a valuable part of the classroom community Engaging Kiara's funds of knowledge(s) in productive ways through her classroom interaction was significant for Maria's learning to teach.

In another instance, Maria's increasing instructional and observation time became important in connecting science to other areas of student's lives—especially towards supporting her view of social justice. For example, Maria had an initial belief that social studies and language arts would be better subjects to be able to support humanizing relationships between youth and societal effects related to equity. However, she leveraged her view of science in ways that would help support youth to learn in other subject areas. For example, youth in language arts were supported in writing an argumentative piece about their experiences with engineering design in the tools, community knowledge(s) and practice(s) they needed to create their inventions. Here, Maria wanted to leverage these important connections between science and their lives and offer a space through an already existing practice(s) of writing personal pieces through their language arts class. In another example, Maria wanted to teach about sharing and equity in resources like the materials they used in engineering design to teach about fractions. These are important connections that Maria was able to build, because of her increasing experiences teaching and being viewed as a teacher (not co-teacher, but as an instructional decision maker in Ms. W's class to support her youth) (Figure 5.8).

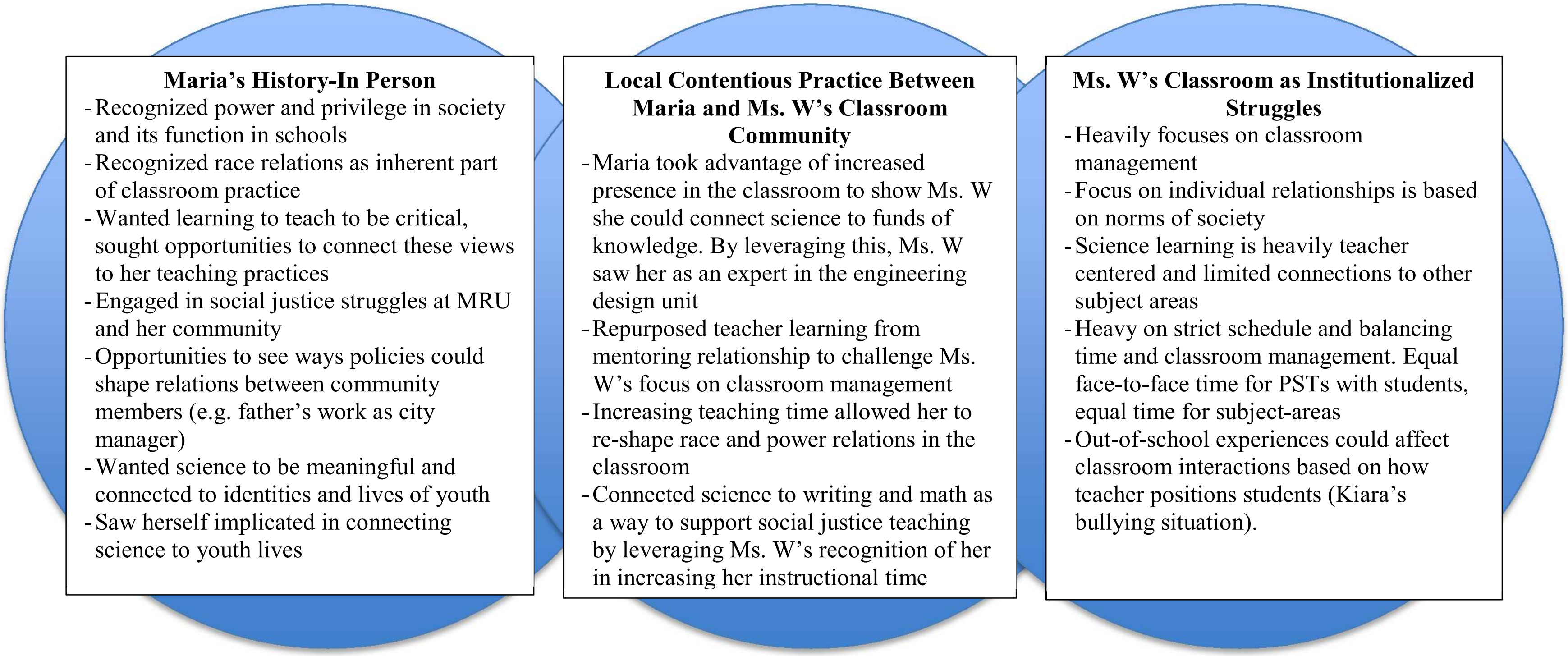

Figure 5.8: Relations between Maria's history in person, institutionalized struggles and local contentious practice.

Discussion

In this study, I presented findings from Carol, Sophia and Maria's enactments as approximations of practice during a six-week engineering design unit at Liberty Spanish Immersion School.

All three teachers had vastly different experiences which were driven by how local contentious practice(s) were developed from their own teaching views through their histories-in-person and the institutionalized struggles evident within the broader culture of the classroom communities in which they enacted their views of YCEO science teaching. In this discussion, I present a cross-case analysis of PSTs enactments as practice in their field experiences. I argue that PSTs took different approaches to implement YCEO practices and these were due to the ways their histories in person interacted within the institutionalized struggles of the broader classroom culture. These tensions in local contentious practice forged new opportunities to shape and reshape ways to support meaningful science learning for youth and themselves as developing science teachers in their learning to teach.

In each of the three PSTs enactments there is evidence that different interactions between HiP of the PSTs and the institutionalized struggles within the field classrooms created different opportunities to work through and leverage their views of YCEO practices. Critically important to the learning in this chapter is that views of YCEO's for each of the PSTs were dramatically different and dynamic. Although all three PSTs participated in the same methods course, they each had vastly different views of how to uphold youth knowledge(s) and practice(s) in their science field classrooms, and those views where shifted depending on how these interacted in local contentious practice.

Carol's view of YCEO science teaching was primarily driven by unpacking and upholding individual youths' repertoires in their classrooms. She wanted to make sure that each student, regardless of who they were or their ability status, were being included in the broader classroom culture. However, in her field placement, this view was not realized. Ms. C's focus on Spanish Immersion, limited opportunities to engage culturally diverse youth and youth with disabilities and centering her instruction as the only resource for learning (e.g. Andy not being in class prompted Ms C to think he did not know the content). Rather, the tensions turned into practices that in Carol's view could become educative for Ms. C. She worked with Andy to leverage his funds of knowledge as strengths through the electric art unit, and she also worked with the Kudo Wall group to uphold their counternarratives of the kudo culture Carol noticed in Ms. C's classroom. I argue that Carol's HiP and the interaction with the broader institutionalized culture created an individualized focus in her YCEO practices. This focus allowed her to recognize tensions inherent in the culture of the classroom and relationalities between Ms. C and her students.

Sophia's experience in this enactment was different. First of all, Sophia's HiP and her own view as a PSTs going into the field was limited. She was critical of her own understanding of how to enact equity-oriented teaching. Furthermore, her limited experiences teaching culturally diverse students and a white, middle class Christian, prompted her to seek opportunities to gain experience, but she was not having luck in her mentor teacher's classroom. Although her relationship with Ms. L was meaningful to her, she noticed that Ms. L limited her instructional time because as an expert teacher, she had her own views of how to impart teaching knowledge on Sophia. However, this view was due to her own comfortability teaching the same way and, in the practices, she is comfortable with. However, once the EDU began, Ms. L was quickly challenged to take up a new form of teaching that called for leveraging strengths in students community knowledge(s) and practice(s) through working on content and practices in engineering. Ms. L was not prepared for this. Because Dr. C offered an opportunity to Sophia to work in Ms. L's classroom to support in instruction, Ms. L immediately recognized her as an expert on the curriculum and positioned her as a co-teacher in her classroom. This happened despite Ms. L not having recognized Sophia before during her observations as that expert teacher.

Not only was Sophia's role flipped, but now she was put in a position to work towards improving her teaching practices at a faster rate, taking up on the unit and even challenging herself to learn the content and practices of engineering as if she herself was a student.

Sophia's HiP was not only in tension with the institutionalized struggles of the teaching practices of the classroom, but it also came in tension with Ms. C's own HiP and struggles to teach herself. In addition, this focus on co-teaching, although provided more instructional time and approximations of practice, it also limited Sophia's ability to become an independent teacher. She overcame this by shaping practices through learning the discourse Ms. L leveraged when she recognized Sophia as a co-teacher. In doing so, when Ms. L interjected during Sophia's instruction, she used that same discourse to center the instruction back on her. I argue that Sophia's HiP and interactions with the cultural-historical interactions in Ms. L's own HiP as a teacher and those of her classroom created a classroom focus in her developing YCEO practices. This focus supported Sophia to recognize tensions inherent between her developing instructional practices and the broader classroom culture.

Maria's enactment experience was different from the other two PSTs. Primarily because Maria's view of YCEO practices were related to societal and institutional pressures that she saw being reproduced in her field classroom. Early on, she noticed that resources and instructional supports for youth and teachers in the Spanish immersion program were different than those in her field classroom. In addition, her mentor teacher, although supportive, was increasingly focused on micromanaging her field classroom. This micromanagement as an institutionalized struggle for Maria directly impacted her contentious practice to enact her social justice view of equitable science.

Hence, in taking both the inequities in the supports of the school between classrooms, and the inequities in Ms. W's upholding the ways youth should succumb to the power of their positioning in society, Maria sought to increase her instructional time so that she could challenge these notions in her teaching. By doing so, over the course of her enactment, showed Ms. W through interactions with students how to leverage and support youth funds of knowledge(s) through the unit. Because Ms. W saw her work becoming meaningful to students, and also because Maria was spending much more time in her classroom due to transportation issues, she allowed her more independent instructional time. Maria then learned to shift conversations in the classroom to limit Ms. W's micromanaging of students, and instead centered their relationalities in the classroom. I argue that Maria's HiP and interactions with the cultural-historical interactions in Ms. W's created a systemic view of classroom culture, where she continuously sought to challenge systemic inequities that were reproduced in the classroom culture which mirrored youths' positioning in society. Table 5.3 shows relationships between LCPs', enactments, YCEO's and generative teaching practices.

Table 5.3:
LCP(s) as Supporting to Shape Instructional Focus and Developing YCEOs

PST(s)	LCP(s)	Instructional Focus	YCEO's
Carol	Tensions between inquiries in classroom culture that limited meaningful individualized learning for youth, views of YCEO science teaching and HiP language repertoires for teaching	Tensions led to focus on individual student interactions	Opportunities for her teaching practices to leverage youth's funds of knowledge towards shaping Ms. C's institutionalized classroom culture
Sophia	Tensions between her view as an expert teaching by her mentor teacher and inexperience working with culturally diverse youth on a unit that prompted teachers to work towards equitable science teaching	Tensions led to focus on classroom interactions where she maximized her time in the classroom as an opportunity to increase her learning to teach	Opportunities for co-teaching led to increasing instructional time and pushed Sophia to increase her content knowledge and pedagogical practices to support classroom instruction
Maria	Tensions between her view of inequities of power and privilege in society and Liberty's focus on Spanish Immersion, and how those inequities were reproduced by the microcosm of the classroom culture through Ms. W's instructional practices.	Tensions prompted Maria to create opportunities for Ms. W to view her uptake of youth knowledge(s) and practice(s) as strengths to increase her instructional time.	Opportunities to increase instructional time pushed Maria to not only approximate practice, but also leverage her teaching in other subject-areas by connection engineering design learning to language arts and mathematics instruction.

Limitations and Future Learning

There are several points in this chapter that need further unpacking, especially when it comes to race and racism in educational spaces. One of the main goals of this paper was to recognize the importance of how different opportunities in learning to teach and classroom communities where this learning to teach develops can greatly affect the ways that PSTs develop practices, and the range of enactment of practices that are youth-centered and equity-oriented. Particularly, the role of race and racism was not too evident in this work, and although all the teachers attempted to unpack those notions further, it was difficult as they felt their own HiP (e.g. Carol and Sophia) did not give them the experience to discuss or unpack this further. In addition, although I argued that Maria was the most critical of the three PSTs—mostly because of her intention to recognize and transform issues of power in her classroom—there are several examples in this piece where she does essentialize cultural—historical notions of students' experiences (e.g. students not receiving the same education that she did where she is directly making the assumption her education is better than the student's education). Although it is important to be critical of these notions and to learn from them to transform views for PSTs in future work, it is also important to recognize when there is an attempt by PSTs to transform practices in support of their students—in trying to be critical of their own privilege. I take this stance because of my close work with Maria and our long drives and discussions which tell me that her critically is intentional and she learned over time to work on ways she could minimize essentializing and viewing students by their traits, but rather by their individual practices. I learned that finding ways to support this learning for PSTs, especially for white middle class female science teachers using a Critical Race Theory lens is one of the goals I hope to continue fostering through this work.

These cases were critical in unpacking interactions between PSTs and their views of youth-centered, equity-oriented practices (and the range of ways they tried to enact these practices) and how these came in tension with the local practices in their classrooms. This work builds on previous chapters of the dissertation by unpacking how imaginaries as practice can be shaped by enactments as practice. Learning to teach for equity in a methods course is not enough as these enactments are shaped by local classroom practice.

CHAPTER SIX:
IMPLICATIONS AND NEXT STEPS

This dissertation means the world to me. Not only because of the deep, generative, intersectional and long-term impact it has had on my doctoral career, but also in the ways the different pieces in each of the chapters led to a larger goal of theorizing a practice(s) -based approach to developing youth-centered, equity-oriented practice(s) in science teacher education.

I argue that the findings in chapters three, four and five added to the knowledge-base in science teacher education by providing a new framework to better understand how youth knowledge(s) and practice(s) through imaginaries as practice and enactments of practice can lead to a generative, relational and intersecting approach to merge theory and practice(s) in science teacher education. Figure 6.1 shows my initial thoughts on theoretically connecting the themes and learning from the three chapters.

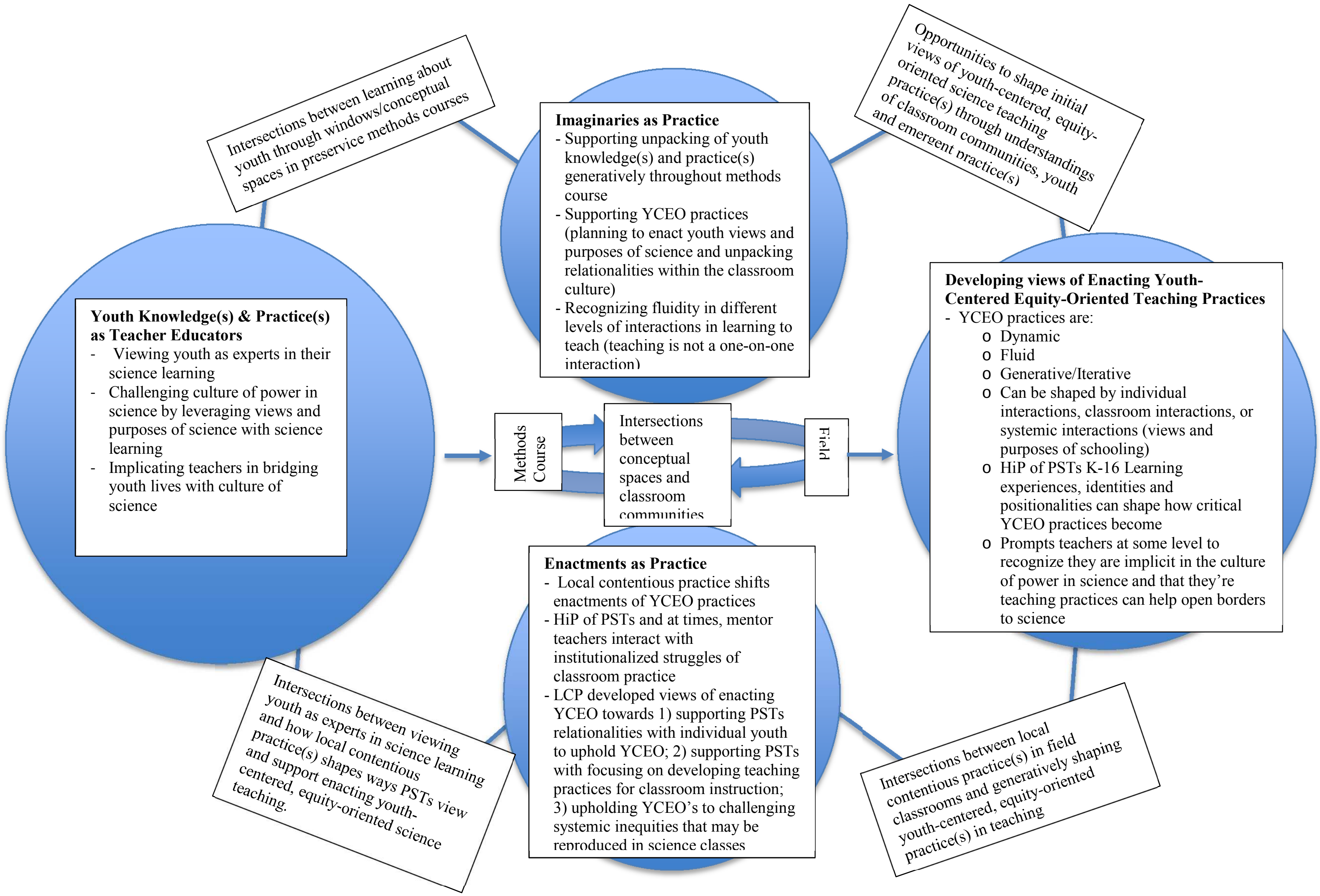

Figure 6.1: Practice-based approach to supporting development of youth-centered, equity-oriented practice(s) in science teacher education.

Overall, I argue that when you intersect theory (methods courses) and practice (field) in ways that support views of youth knowledge(s) and practice(s) (e.g. as teacher educators and experts in their science learning), opportunities can be created to open doors for PSTs to imagine practice(s) that can support youth in meaningful science learning through their enactments. I particularly echo what Carter Andrews (2009) found in her piece in regard to how service-learning experiences in methods courses supported reflection processes in students that led them to become your "social justice oriented in their thoughts about urban teaching" (p. 287). Arguing towards shaping learning to teach opportunities around this constant movement between the field and a methods course can be a way to support equity-oriented work in science teacher education.

Furthermore, if opportunities to enact are long-term, impactful and centered on continuous teacher learning from and with youth, then PSTs can further shape their classroom communities to create meaningful spaces for science learning. It is important to note that intersections between these conceptual spaces (imaginaries developed in methods courses and views of local contentious practice(s) during enactments in teaching experiences) need to be further interrogated and supported to understanding how early understandings of inequities can be shaped and supported through generatively over time.

One thing to note is that this dissertation focused on three important connections. The first is trying to unpack youth-centered views of how science functions in their lives. Chapter three focused on three youth's experiences with the culture of power in science and how through engagement in/through science for communities they were able to see how community engagement was not always upheld in the spaces where the legitimization of science really mattered for their success (e.g. school). The findings of that piece helped to understand what it means to initially support students in ways that are youth-centered and equity-oriented. Chapter four was an attempt to center these views around designing a methods course that unpacked these youth perspectives around the interplay between the TE 400 course, PSTs own learning experiences and the field. This interplay led to two important practices as well as a new theoretical view of *equitable imaginaries* where PSTs initially learned to unpack and understand that science is not the same for everyone and that practices, materials/resources, and learning experiences can be related to ways science has classed, gendered and raced students. Although the findings don't indicate a radical shift or uptake of these ways of thinking in PSTs, they do show that when youth are centered in PSTs learning, especially in science, PSTs begin to implicate themselves in making connections and bridges between the content and the students they are going to (or will) teach. Chapter five showed that PSTs do have initial views of youth-centered, equity-oriented science teaching practices and long for experiences in the field that helps them to support that framing, but local practice can shape completely the types of experiences PSTs have in their developing work and practices. In addition, the scope of youth-centered, equity-oriented practices can change based on these local contentious practices that are created between their views of YCEO teaching and the way they are allowed to enact them in their developing work as PSTs. What that chapter showed is that with these varying experiences, their instructional foci using YCEO practices went from individual, to classroom to systemic—and although the goal is to recognize systemic inequities in practice, these are more difficult to achieve—even if the PSTs have the best intentions in doing so (e.g. Carol and Sophia)—when PST(s) are not allowed to center these views (especially of race, classed and gendered notions) as part of their field teaching experiences.

Hence, this view of practice-based science teacher education calls for iterative unpacking of views of youth, within the culture of the classroom, in science classes over time and needs to be developed generatively through various teacher education program supports where PSTs can analyze their emerging views of practice(s) in their field classrooms. This learning should provide tools so that this learning can be carried through their novice years so that these emerging views generatively contribute to their teacher learning over time.

Figure 6.1 shows a new approach to combining youth knowledge(s) and practice(s), methods courses and field teaching experiences connected under the umbrella of youth-centered, equity-oriented science teaching practices. I believe this new approach can support teacher education methods courses in science, and programs more generally to integrate these youth-centered approaches in conjunction with already existing practice(s) that support culturally relevant, culturally sustaining pedagogies and pluralistic (Paris & Alim, 2017) in preservice teacher education. However, there needs to be more work in unpacking views of race, racism and other forms of subordination in order to better understand how these views can begin to challenge foundational inequities in science education reproduced by PST(s)—especially in conjunction with how to develop teaching opportunities using already existent frameworks like the Next Generation Science Standards.

Also important is how this view supports and maintains the need for teacher education programs. Teacher education programs are necessary and impactful in the lives of future teachers. Given the growth of alternative credentialing and decreased funding for education programs, it is necessary to support new approaches such as this that combines these theoretical and practical underpinnings in teacher learning through community-engaged and service-oriented dispositions. This dissertation was an attempt to do so through grounding a new theoretical approach. However, this work needs further investigations, in different settings and with different populations of PSTs, students and other stakeholders.

The rest of this chapter summarizes the implications of the findings from the studies reported on the previous chapters and are grouped into three themes: 1) further research on youth-centered, equity-oriented science teaching practice(s), 2) science teacher education and science teacher learning and 3) research on equity in science education.

Implications for Research on Youth-Centered, Equity Oriented Science Teaching Practices

Findings in this dissertation suggest that as a field science teacher education, and science education more broadly must expand views on what it means to support views of youth-centered, equity-oriented science teaching. Although this study dealt with understanding these practice(s) through ways preservice service teachers imagined (Chapter 4) and enacted (Chapter 5) these practice(s), expanded views of these practice(s) need to be studied in K-12 science education more broadly. These include supporting educative professional development of in-service teachers and support of programs in schools, classrooms and out-of-school spaces that can build instructional program coherence around themes of centering science that matters and action-taking in science in classrooms. These are especially true in classrooms where PSTs , in-service teachers and education programs more generally believe that high amounts of material resources are needed to support a type of science education that is impactful for youth. Instead, there should be a focus on how teaching practice(s) and instructional decision-making should shift to become generatively more equitable and youth-centered recognizing funds of knowledge and repertoires of practice as important resources for science learning. However, this view requires recognition that learning does not only take place in the confines in the classroom through uptake of a particular discourse, content-based knowledge(s) and practice(s), but rather there needs a focus on a type of institutional shift where opportunities are afforded to youth to see themselves, their views and purposes meaningfully in science learning.

Through this same end, chapter three of the dissertation showed how youth, especially those who have been minoritized and fared worse from educational policies that have raced, classed and gendered youth in science purposefully hybridize, practice(s), tools, social networks and relationships across spaces and over time with science learning in meaningful ways. One way to look at the findings in chapter three in relation to broader systems and sensemaking of how these systems impact youth is through understanding how their own “critical consciousness” (Freire, 1973) of engagement with science learning, created opportunities create counternarratives of science learning in ways that oppress them and their communities. They also created multimodal artifacts that became expansive tools to see how their science learning moved across spaces and over time, allowing for resources, people and places to contribute to the vertical knowing-making and knowledge(s)-sharing between youth and communities through the ways they created *counternarratives of the culture of power in science.*

For PSTs , in chapters four and five, and along the same lines of viewing youth practice(s) through a critical consciousness of their work as developing teachers supported a new, theoretical way of supporting youth-centered, equity-oriented science teaching practice(s). By unpacking how classroom communities are shaped by the culture of science and understanding the humanizing aspects of youth in relational ways in a methods course focused on youth as teacher educators, PSTs saw how families, friends and community members are all involved in the ways science learning can be merged through cultural practice(s) of love, care, compassion for community. By providing an initial view of how counternarratives of the culture of power in science are told by the three youth in chapter three, and then leveraging this new-found knowledge(s) during imaginaries in methods courses and enactments in classroom communities, we can move towards a new way of leveraging a pluralistic, culturally sustaining view (Paris & Alim, 2017) of science teaching and learning through developing views of youth and equity early on in teacher education. Together with other frameworks that have been developed over years of research (Ambitious Science Teaching Practices, High-Leverage Practices) these together can become a powerful force in advancing the educational debt owed to minoritized youth in science education.

In order to support this view and move research forward, science education must recognize that access to science should not fall on youth to take on the culture and discourse of science in classrooms, or that equity in science is merely a resource issue. Rather it should invoke a careful, relational view of youth in ways that seek to leverage an epistemic understanding within classrooms-between teachers and youth, youth with each other, and all with science learning. In addition, it asks PSTs to implicate themselves as bridges between youth knowledge(s) and practice towards this equitable science learning. Equity and culture should not be the means to the end of science content and practice(s) learning. It should be the end, and the means should be the careful and purposeful hybridity of youth funds of knowledge(s) and repertoires of practice(s) with science content and practice(s) in culturally sustaining ways.

Chapter four helped to understand how PSTs can develop imaginaries of these practice(s) -based youth-centered, equity-oriented approaches in science learning while chapter five allowed PSTs to see these approaches in practice. They did so by interrogating forms of power and privilege—either by relating individually, classroom-wide, or systematically with equity-issues in their science classroom. At times, these were beginning ways to become conscious of how some (not all) cultural/social/educational/political/other structures that support or inhibit meaningful science learning can be systemic in its practice(s) . By understanding these enactments and the ways they were shaped by local contentious practice(s) towards supporting their individual views of youth-centered practice(s), a more equitable view of science teaching and learning can be built together.

Implications for Science Teacher Education and Teacher Learning

First and foremost, this view of youth-centered, equity-oriented science teaching to teacher education and teacher learning (as a field) is not new. However, the belief of being able to merge theory and practice(s) towards a systemic view of how these practices become generatively more youth-centered and equitable is new. In my experiences, as a learner, science teacher, researcher and teacher educator, I saw how it can be possible to build a new theoretical approach to youth-centered, equity-oriented science teacher education that carefully merges science methods courses with practice(s) in the field.

The diverse nature of teacher education programs and how programs each have their own identity and view of how teachers should professionalize themselves, made it difficult for me to only theorize this view by analyzing the literature. This dissertation is an attempt to work through this in/with a teacher education course that focuses on teaching science to diverse learners and creating a new way to sustain this learning through three teacher's experiences in the field teaching engineering for sustainable communities in ways that upheld their view of YCEO in methods courses.

It is important to add that other researchers (e.g. Birmingham, 2013) have studied ways that teachers can take on youth views of science learning (e.g. identity) and how these helped shaped practice(s) in classroom. This equity view in science is not new. However, my research in this dissertation attempts to show a type of longitudinal reflection of teachers working from experiences of youth in meaningful science learning. I placed those same youth in a position where they were experts in their own science learning either through the multimodal cases they developed as well as bringing them into the methods course as experts of their learning experiences. I then focused views of youth in science field classrooms to be centered on their knowledge(s) and practice(s) expertise in community and then leveraged these understandings so that teachers could find ways to enact their emerging views of how they see youth-centered, equity-oriented practice(s). All in all, I have found that one can provide a sub-set of tools to understand youth funds of knowledge(s) and repertoires of practice(s) in science learning, but there needs to be more research on understanding how local contentious practice(s) in field classrooms shape these views. Not all teachers enact the same views because field classrooms have different cultures. Hence, this is why in Figure 6.1, I argue that youth-centered, equity-oriented teaching practice(s) are generatively developed. The next step in this work is to understand how novice teachers in their new classrooms develop these practice(s) and sustain them, and how they shape classroom communities towards a culture that itself becomes a counternarrative to the culture of power in science.

Chapter four of the dissertation showed three important points in understanding equity in science teaching, which could combine with previous studies in the field. The first is that PSTs hold their own personal views of science learning and these views are often carried into their science teaching. Many times, these views are not unpacked in methods courses and the ways these PSTs see themselves as science youth, given the power science has through its symbol of power and status, transfers into their own ability to think they could enact good science teaching. Science needs to become accessible, not only to the youth, but also to the PSTs that are learning to teach, because they too are carrying these historicized notions of the culture of power of science in their own lives. Being able to see that science is accessible to youth, and that they take action in their science learning early on in their methods courses, I believe that can be a new way to unpack the settled notion of science in education.

The second learning point from chapter four is that PSTs need to be supported in understanding what about family, communities, home and other resources can be leveraged meaningfully in science learning. Many of the PSTs who participated in the study changed their mindset around what constitutes expertise in science. Not all ended up viewing youth as experts in science content, but they did see youth as experts in the problem spaces for which they used science to solve those problems (engaging in community ethnography, tinkering in after school spaces, making designs). This is why having the opportunity to view youth, either through multimodal cases of science learning, or delving into ways that youth can participate as teacher educators is extremely important—because this flips the question from: what do I need to teach today to what do youth want to learn today? Science itself is the study of the world around us, if science teaching continues to contribute to a settled and never-changing notion of the world, even though people in power who use science as a way to control, shift, change, manipulate it's use, then youth will never be able to use the tools of science to change their lives. Teacher education and teacher learning need to be part of the conversation in science for equity and social justice.

The third learning point involves ways in which participating scientific discourse leads to questions on whose knowledge(s) matters and why? By providing new ways to imagine relationalities, we are creating a new way to support a community view of science within classroom spaces and building on the relationality dynamics through a view of power and privilege. Here, more research needs to support a sociopolitical view of science learning where teachers and teacher educators recognize youth as (one type of) experts in their science education.

Implications for Research on Equity in Science Education

This study has tremendous implications for equity in science education. Returning to Tate's argument of science education as a civil right, we need to better unpack what it means to teach all youth science in equitable ways. As stated before, access to science is not only limited to supporting access to resources or making science accessible through content/engagement with practice(s) of science that closely resemble those of the culture of power in science. This work also calls for recognizing that minoritized youth have been disenfranchised systematically from a socially just science education and that there is a debt owed to them by the field which needs to be addressed. By positioning youth as experts in their home and communities related to the problems and perspectives needed to answer questions/designing solutions that will help those communities and teaching teachers to view this as a way to center their instructional practice is paramount to answering (a) question of equity in science education. The best way to support this is to continue working to unpack ways youth counternarratives can challenge traditional and colonizing views of science learning and providing expansive ways for PSTs to be able to apply this work in the field early on in their work. It is not only about recognizing youth' views of meaningful science learning through a power and privilege lens where they can see themselves as important in pushing back against systems of oppression reproduced by science and schooling more generally. It also involves a purposeful disruption of knowledge(s) hierarchies as to whose knowledge(s) matters in the learning to teach in/within spaces. Furthermore, I want these developing science teachers to be in constant dialogue with their fields and with the youth and that these practice(s) continue throughout their teaching career.

Science education needs powerful sociopolitical shifts that unpack what it means to know, who has the power, and why it matters in science learning? This dissertation is only one way to view this and I look forward to a plentiful career trying to answer this question with youth, communities and teachers, in my research moving forward.

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