8-2021

Sensemaking for Equity and Agency : STEM Teacher Learning Through a Community of Practice Model

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SENSEMAKING FOR EQUITY AND AGENCY: STEM TEACHER LEARNING THROUGH A COMMUNITY OF PRACTICE MODEL

A DISSERTATION

Submitted to the Faculty of

Montclair State University in partial fulfillment

of the requirements

for the degree of Doctor of Philosophy

by

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August 2021

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MONTCLAIR STATE UNIVERSITY

THE GRADUATE SCHOOL

DISSERTATION APPROVAL

We hereby approve the Dissertation

Sensemaking for Equity and Agency: STEM Teacher Learning Through a Community of Practice Model

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Doctor of Philosophy

Graduate Program:
Teacher Education & Teacher Development

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July 27, 2021

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ABSTRACT

SENSEMAKING FOR EQUITY AND AGENCY: STEM TEACHER LEARNING THROUGH A COMMUNITY OF PRACTICE MODEL

by Karen Anne Woodruff

The current vision for science education is to improve learning for all students by enacting teaching practices that make rigorous science content accessible to diverse learners. Science education, as a field, is shifting focus to be practice-based and equity-centered as students and their ideas become the focal point of the profession. The enactment of this vision calls for professional learning opportunities for teachers that support sensemaking and enactment of reform-based practices. This design-based study is an exploration of how ten science teachers negotiate issues of equity and professional agency in their teaching of the science and engineering practices through identified problems of practice. Using qualitative methodology, I describe a critical professional learning model, a collaborative online community of practice, and the productive tensions that emerged. Some participants demonstrated that they could focus on the Science and Engineering Practices with attention to equity when they made purposeful decisions to center their students in the everyday decisions of teaching. Those with the autonomy to enact shifts to their teaching selected high leverage practices as tools for centering student ideas and cultural experiences. This study contributes to the gap in understanding about support for in-service teachers taking up equity practices in their work and responds to the call for teachers to explore innovations to their teaching in collaborative spaces.

***Keywords*:** NGSS, equity, science and engineering practices, professional development, community of practice

ACKNOWLEDGEMENTS

I am a sincere believer that collaboration and reflective discussion makes effort of any kind stronger, and the doctoral journey is no exception. The MSU Teacher Education, Teacher Development program is nationally recognized because of the amazing faculty that dedicate their lives to more equitable and just education systems for all students. Among this remarkable group of people, I would like to express my deepest appreciation to my committee, Dr. Emily Klein, Dr. Mayida Zaal, and Dr. Doug Larkin. I am extremely grateful to Doug for guiding, encouraging, and believing in my work by providing opportunities to deepen my understanding of where I can contribute to the field of science teacher education and support the natural curiosity of all students. I am so appreciative for constructive insights from my critical friends Liz Carletta, Catherine Gaynor, and Suzanne Poole-Patzelt and recognize the many ways that my classmates pushed me to think more deeply about my work and purpose as a critical educator.

The participants in this study have my sincere gratitude. They exemplify the dedicated, passionate individuals that support students understanding of the natural world and strive to be as good as they can be at their work. Thank you for embarking on this journey and for allowing me to learn from you.

Most importantly, I would not have been able to accomplish this goal without the unrelenting support of my husband Gregg and the love of our three wonderful children. The doctoral journey requires tremendous work and sacrifice. I hope that our children recognize that they can accomplish anything they wish in this world and value the importance of friendship and collaboration along the way. I am forever thankful for my friends and colleagues, my parents, in-laws, and siblings–thank you for your love and support.

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Chapter One: Introduction

The current vision for science education is to improve learning for all students by enacting teaching practices that make rigorous science content accessible to diverse learners. Science education, as a field, is shifting focus to be practice-based and equity-centered as students and their ideas become the focal point of the profession. This goal requires that teachers recalibrate their efforts on attending to students, their existing conceptions, unique experiences, and cultural funds of knowledge that they develop through interactions in their communities and families, which can inspire meaningful learning connections within the classroom. Classrooms are communities of learners−diverse learners−and each and every student deserves the opportunity to engage with the practices that represent how scientists and engineers explore and think critically about the natural world. Providing access to all students involves recognizing existing inequities in the structure of education and questioning how educators can make changes to their teaching to value all students and they ways in which they see and understand the world around them (Calabrese Barton & Tan, 2020). This critical approach to science education positions teachers as politically, socially, and culturally engaged individuals who focus their teaching on transforming society through their practice (Kohli et al., 2015).

Decades of education research by equity-minded scholars and educators provides a foundation for the critical work that needs to be done in science education to center students as the focus of teachers' pedagogical decisions. However, existing systems of teacher education and in-service teacher development are in opposition to equity centered teaching. Few teacher

education programs prepare teachers with a social justice orientation and in-service teachers rarely have the support required to unpack and make sense of the practices necessary to enact equity centered teaching (Darling-Hammond et al., 2019; Kohli et al., 2015). Furthermore, most current classroom teachers did not learn science in classrooms where teachers facilitated learning with an equity lens or a practice focus (Marek & Methven, 1991; Penuel et al., 2007) and their conceptions of teaching science to diverse students may be similar to their experiences as high school and undergraduate students (Windschitl, 2003). While teachers readily agree that they wish to see all their students succeed, most often their development as teachers does not include a critical education lens and the practices they prepare to use in the classroom do not support the vision of rigorous science education and high expectations for all students. Teacher's conceptions of teaching and the vision they have for their students simply do not match the practices they learn to enact (Hammerness et al., 2005; Kennedy, 1999).

Presently, scholars and educators in the science education community are grappling with how to address systemic inequalities in science education, present since the inception of formal education in this country (Nieto, 2000). Despite widespread recognition that students' ideas must be central to the work of teaching (Beeth & Hewson, 1999; Larkin, 2019; Windschitl et al., 2018), most science teachers lack the preparation and support to make sense of and enact practices that support students. The oppressive power dynamics that have historically marginalized non-dominant individuals remain prominent in classrooms (Calabrese Barton & Tan, 2020). The current movement to shift teaching practice, which leverages the work of critical scholars, is especially important for students from nondominant groups; those historically marginalized because of their race, ethnicity, gender, or socioeconomic status, whose voices and

experiences have not been represented in science education. These efforts are part of current national reform in science education.

To a greater extent than previous science education reform documents, the Framework for K-12 Science Education: Practices, Crosscutting Concepts and Core Ideas (National Research Council, 2011) and the subsequent Next Generation Science Standards (NGSS Lead States, 2013; Reiser et al., 2017; Schwarz et al., 2017), address issues of equity, diversity, and widespread disparities in education. The Framework authors dedicate a chapter to equity and diversity (Chapter 11) and the NGSS appendices include suggestions for supporting "economically disadvantaged students, students from major racial and ethnic groups, students with disabilities, students with limited English proficiency, gender, students in alternative education programs, and gifted and talented students" (NGSS Appendix D, p. 7). The authors discuss possible classroom strategies and highlight the specific policies intended to support historically underserved groups. While many remain critical of the economic superiority approach that is evident in reform documents−namely the desire to remain competitive globally through innovation in the Science, Technology, Engineering, and Mathematics (STEM) fields−current language attends to equity and diversity in more significant ways than ever before (Rodriguez & Morrison, 2019).

The NGSS includes a trifocal perspective to science that brings together a refined vision of how scientists take up the work of learning about the natural world with current knowledge of how students learn best. This approach includes the interweaving of content, referred to as the Disciplinary Core Ideas, the concepts that are common across scientific disciplines, known as the Crosscutting Concepts, and the Science and Engineering Practices (SEPs), the behaviors in which scientists and engineers engage that can be replicated in the classroom to ensure student

engagement in inquiry practices (Figure 1). Teachers are tasked with facilitating opportunities for all students to interact with science. The Framework authors request that students "engage in the practices and not merely learn about them secondhand." They explain, "students cannot comprehend scientific practices, nor fully appreciate the nature of scientific knowledge itself, without directly experiencing those practices for themselves" (National Research Council, 2012, p. 30). The Framework authors call for attention to student diversity in the classroom and the many cultural and community-based experiences that students bring to the learning process, stating, "when provided with equitable learning opportunities, students from diverse backgrounds are capable of engaging in scientific practices and constructing meaning in both science classrooms and informal settings" (NGSS Appendix D, p. 1).

Figure 1

The Next Generation Science Standards Science and Engineering Practices

Asking questions (for science) and defining problems (for engineering)
Developing and using models
Planning and carrying out investigations
Analyzing and interpreting data
Using mathematics and computational thinking
Constructing explanations (for science) and designing solutions (for engineering)
Engaging in argument from evidence
Obtaining, evaluating, and communicating information

The attention to equity and diversity in NGSS addresses a well-established need in the literature and national education reports to attend to disparate achievement levels between Students of Color and White students. Approaches to teaching science, including the stories told, voices shared, and ways in which various races and ethnicities are represented in the scientific community, historically represent Eurocentric perspective. Students of Color are at a disadvantage when their cultural ways of knowing are not represented in the classroom

(Calabrese Barton & Tan, 2020; Carlone & Johnson, 2012; Delpit, 1988). When teachers fail to recognize the cultural connections to scientific concepts that they are teaching, students can feel that their experiences outside of school are not congruent with what they are learning in school (Carlone & Johnson, 2012). Furthermore, when teachers hold deficit views of students, families, and communities, students can be at significant disadvantage (Moll et al., 1992). Rodriguez (2015) states that a teacher might have "the best preparation in learning theory, content and pedagogy, but if he or she has not been well prepared to be a more culturally inclusive, respectful and responsive teacher, this individual would likely not be able to establish a productive professional relationship with students and their parents" (p. 1041). As the NGSS continues to be integrated into classrooms across the country, the historical and systemic barriers to equitable opportunities for all students must be made "front and center" if we are to address widespread disparities across ethnic groups (Nieto, 2000).

The NGSS call attention to equity and diversity to a greater extent than past national education reform documents−a step in the direction of recognizing historicized inequities. However, simply stating a commitment to equity does not ensure its realization. Diversity and equity are concepts that are poorly conceptualized, and their meanings vary widely across teaching contexts (Liu & Ball, 2019; Philip & Azevedo, 2017). Rodriguez (2015) contends that the NGSS are one of a series of national science education reform efforts attempting to fix complex issues facing science education by providing structure for what students should know and do in the classroom. Despite appendices that present case studies and examples of teaching practices, the NGSS lacks detail about the specific skills required for teachers to accomplish the type of learning opportunities described. Decades of federal reports and education policy

documents indicate differences in commonly measured achievement levels between Students of Color and White students (U.S. Department of Education, 2019).

Stating goals for equity does not ensure the realization of equity practice in classrooms and new standards are not simply read and enacted with ease (Windschitl et al., 2012). For example, the Framework and NGSS define the specific components of science and engineering in which students should actively engage. However, teachers need support to make sense what SEPs such as engaging in argument from evidence or analyzing and interpreting data look like in the classroom. Documents call for attention to diverse student experiences and cultural connections to content, yet teachers need support making sense of why culture is important and how to enact practices that value cultural assets. Teachers interested in supporting students learning in the context of everyday experiences and their engagement in society and culture need opportunities to take up the work of teaching from a critical lens.

This work, characterized as critical professional development, can support the ideas put forth in the Framework for providing all students with access to scientific knowledge. Programs that support teachers from a critical stance are rarely available to teachers. They are antithetical to the tradition of teacher-centered practices that represent knowledge from a singular dominant cultural perspective; the perspective that remains most often represented in teacher preparation and development programs (Darling-Hammond et al., 2019; Zeichner, 2016; Zeichner et al., 2015). In addition, the deep thinking, unlearning, and relearning necessary in critical equity focused professional development requires sustained programs, well aligned to research-based practices in professional learning (Rosebery et al., 2016). The common models of professional learning offered to most teachers are ill-suited to the work (Banilower et al., 2018; Kohli et al., 2015). There is a significant need to provide teachers with professional development that allows

them to do the challenging work of unlearning oppressive pedagogies and envisioning practices that center students. If in-service teachers wish to engage in equity and justice focused pedagogical methods, then professional learning needs to support examination of the important social and cultural issues they and their students face in schools (Kohli et al., 2015).

In this design-based research study, I describe a professional learning experience of ten teachers engaged in a community of practice that provided a collaborative space for teachers to make sense of equity by selecting and interrogating a specific aspect of their teaching. By self-selecting a problem of practice, teachers exhibited agency over their own learning and were able to work on a meaningful component of their practice as it related to equity and the NGSS science and engineering practices. I describe their work during a 16-week period, when they collaborated in an online space and grappled with challenges and opportunities for taking up an equity-focused approach to their teaching. Using sensemaking as an explanatory framework, I share each participant's process of self-perpetuating change through generative work of improving through reflection and collaboration (Ball, 2009, 2012). Using qualitative methodology, I captured the sensemaking process of each individual within the community to better understand how teachers shifted their thinking about equity and translated those ideas into planning and enactment in their teaching contexts. This model for professional learning and the outcomes of the work contribute to the evolving understanding of how science teachers can be supported in integrating equity into their purpose as educators from within existing structures of education.

Rationale for the Study

Two primary goals guided this research study. First, I sought to provide teachers with a collaborative space to explore issue of equity in their specific teaching environments. Given the circumstances in which all the participants and I were teaching−a global pandemic, widespread

attention to racial injustices, and intense political tensions across the country−I established a space where teachers could work on issues that they identified as important to their teaching. The second goal was to research teacher learning in an online collaborative community of practice. I sought to understand how teachers made sense of equity in their teaching when provided the agency to do so, and how they were able to identify opportunities to shift their practice with an equity lens. I employed a design-based research approach to address these goals.

Design-based Research

Design-based research focuses on creating and studying solutions to challenges in real world contexts. As a form of educational research, the approach encourages exploration of methods that support all learners with effective and powerful learning opportunities, including teacher learners (Penuel & Potvin, 2021). It is an approach used to "reconfigure the roles of researchers and practitioners in bringing about systemic change in ways that make it more likely that practitioners can adapt innovations productively to meet the needs of diverse students and that durable research–practice partnerships can sustain innovations that make a difference" (Fishman et al., 2013, p. 137). Examples of design-based research include networked improvement communities and research-practice partnerships where school districts and researchers work collaboratively to design, implement, and learn from innovative approaches to context specific challenges (Coburn et al., 2013). In this study, the design-based research model supports the iterative development of practices that are equity focused in classrooms where teachers concentrate on science and engineering practices.

Design-based learning can include constructs of identity and motivation within learning spaces and include a transformation of participation approach where learners engage in ongoing and iterative interactions (Cobb et al., 2003; Stromholt & Bell, 2018). As Stromholt and Bell

(2018) maintain, “learning is not just about knowledge acquisition, but is exemplified by shifting roles, knowledge and skills, responsibility, and power” (p.1017). The design of this study is based on four principles of teacher learning that support the study goals. In the following pages, I describe the principles and the supporting literature for each.

Design Principle 1: Research-based Practices for Teacher Professional Learning

This work is situated in the field of science teacher professional development. I present a model grounded in research-based practices for professional learning and designed as a community of practice where teacher agency is valued and encouraged. The study has a teaching practice focus insofar that the work teachers do together is focused on the reoccurring activities of the profession centered on students participating in science practices and how teachers identify ways to center students’ ideas (Stroupe et al., 2020). Teaching practices focus on both disciplinary work and the way in which teachers learn to participate in a community of learners (Stroupe, 2015). Several commonly cited studies contribute to the current knowledge base for research-based practices in professional learning design and implementation (Desimone et al., 2013; Garet et al., 2001; Hawley & Valli, 1999; Loucks-Horsley et al., 2009; Luft & Hewson, 2014; Penuel et al., 2007). While there is a general lack of consensus about the specific ways in which professional learning programs work and the design features that are most beneficial to teacher learning, there are specific common design elements of professional learning programs that claim a positive influence on teacher learning (Kennedy, 2016). Despite this knowledge many teachers do not experience professional learning aligned to research-based practices (Banilower et al., 2018). By identifying the specific features of effective professional learning that appear repeatedly in the literature and recognizing the inconsistencies within existing structures for professional learning implementation in schools, I present an important empirical

basis for this study. The factors that influence the design of professional learning are 1) The Content and Pedagogy Balance, 2) The Current Theory of Action in Science Professional Development, 3) The Importance of Coherence and Articulation, and 4) Duration and Sustained Presence.

The Content and Pedagogy Balance. Despite historical dissention between teacher educators who believe that content is the primary indicator of quality teaching and those that believe teaching practices are also a fundamental component of educating students, reform in science education gives equal value to both content knowledge and science practices through the three-dimensional design of the NGSS, the guiding framework for science education goals. To help teachers build their content knowledge and the skills required to support student learning, professional learning should address both content and pedagogy. Teacher's should have a strong understanding of content and seek opportunities to deepen their knowledge as life-long learners of science (Feiman-Nemser, 2001; Loucks-Horsley et al., 2009). Content knowledge is widely referenced as the most important component of professional learning (Desimone et al., 2013; Supovitz & Turner, 2000). However, a recent review of 28 empirical studies of professional learning implemented in K-12 classrooms, Kennedy (2016) found that "programs that focused exclusively on content knowledge tended to have less effect on student learning" (p. 27).

Teachers do need to explore the content that students are required to learn, identify the gaps in student knowledge, and seek out new or alternative practices to helping students reach these goals (Hawley & Valli, 1999). It is widely accepted that students do not simply soak up knowledge from teachers and require personal experience with ideas in order to develop understanding (National Research Council, 2012). Therefore, the practice and skills required to facilitate student learning deserve significant attention. Both content and practices should be

integral components of effective professional learning (Desimone et al., 2013; Kennedy, 2016; McDonald et al., 2013; Penuel et al., 2007)

Programs that support teachers' development of scientific reasoning skills have a greater influence on student achievement than those that focus on adherence to a specific curriculum (Supovitz & Turner, 2000). Literature suggests that professional learning programs model "inquiry forms of teaching" (Marek & Methven, 1991), "authentic science" (Crawford, 2012) and "engagement with big ideas" (Windschitl et al., 2018). When teaching skills or practices are applied to subject specific contexts teachers can engage students in the learning process. A practice focus requires having a repertoire of teaching tools available to use as needed in support of student learning. A "toolbox" of practices can be learned and implemented in the classroom to provide students with a variety of access points to making sense of content (Windschitl et al., 2018).

The Current Theory of Action in Science Professional Learning. The theoretical guidance for professional learning suggests that teachers are more likely to engage in professional learning when they understand the reason, the 'why' underlying the program design. The vision for science teaching should be carefully shared with all participants in the professional learning and serve as the knowledge and beliefs that support the work. Scholars claim that reform-oriented methods for professional learning are most effective for teacher learning (Penuel et al., 2007). However, if teachers are not aware of the research base that informs reform oriented methods, they may not be willing to "endure the 'how'" (Loucks-Horsley et al., 2009, p. 31). Professional learning should include opportunities for teachers to understand the theoretical basis for what they are learning. Simply having new knowledge does not ensure that teachers will enact that knowledge (Lee et al., 2004). Hawley and Valli (1999)

state that professional learning must engage teachers' "beliefs, experiences, and habits" (p.143) so that they understand why the change is important. When teachers do not understand the reasoning for why the change is being requested or how it impacts their specific classroom context, they can become cynical and disengaged (Hawley & Valli, 1999).

Furthermore, teachers need to experience the learning themselves to make sense of how it will be helpful in their classrooms and should have access to research results that serve as evidence for change (Desimone et al., 2013; Hawley & Valli, 1999). Loucks-Horsley et al. (2009) state that all professional learning needs to be designed with the knowledge of learners and how they learn. They claim, "when teachers experience and reflect on how students learn, they are better able to understand why certain instructional strategies are more effective than others, thus enabling them to provide powerful learning experiences for their students" (p.53). Both the design of the professional learning and the expectations of teaching after the professional learning should be grounded in the theoretical knowledge about how learners construct new knowledge, how prior knowledge influences learning, the way in which learners make sense of new knowledge over time, the influence of experience on knowledge development, and the recognition that all learners are capable of learning (Loucks-Horsley et al., 2009).

The Importance of Coherence and Articulation. When the goal is to ensure coherence between professional learning and its enactment in classrooms, then it becomes important to attend to the alignment between the goals of the professional learning and those of the school setting and individual teachers (Desimone et al., 2013; Loucks-Horsley et al., 2009; Penuel et al., 2007; Supovitz & Turner, 2000). Supovitz and Turner (2000) state that there is an intimate relationship between staff development and school development. Teachers can face a "dizzying array of conflicting demands" (Penuel et al., 2007, p. 932) that can have an influence on their

ability and willingness to take up change. The barriers and supports provided in their teaching context can be a significant factor in how teachers interpret innovations to their practice (Desimone et al., 2013; Penuel et al., 2007). Teachers may individually engage in innovative teaching practice, however, school change is not possible without a coherent understanding of the purpose and a collaborative environment for problem solving (Bryk et al., 2015; Hawley & Valli, 1999). Penuel et al. (2007) state that teachers need direct experience with reform practices and they reference the use of apprenticeships with scientists as a model for providing teachers experience with science practices. Teachers who are expected to facilitate learning in specific ways must experience the learning process themselves. This experience is especially necessary during the current period of reform because most science teachers learned science in markedly different ways than they are being asked to teach (Marek & Methven, 1991; Penuel et al., 2007).

Duration and Sustained Presence. Teacher education professionals acknowledge the value of sustained professional learning that supports teachers in making meaning of new ideas over time. Reforms are often demanding on teachers and may be in contrast to teacher's practical knowledge (Van Driel et al., 2001). In many cases teachers are asked to make significant changes to their teaching, especially during periods of reform (Crawford, 2000; Reiser, 2013). As learners, they require time for processing new ideas. In a study of a professional learning program focused on inquiry-based teaching practice and investigative classroom culture, Supovitz and Turner (2000) found a dramatic difference in the effectiveness of the professional learning program for teachers who experienced more sustained engagement. They found that with increasing time (they compared 80 hours and 160 hours) teachers benefited more deeply from the experience.

Despite widespread recognition that short duration workshops, such as the common one- and two-day events commonly offered in schools, do not support sustained change in teacher practice, many districts persist in offering them. This is likely because they are time and cost efficient and fulfill state requirements (Desimone et al., 2013; Loucks-Horsley et al., 2009). Over two decades ago Darling-Hammond (1997) called on teacher development programs to reform programs of support for professional teachers, citing the unproductive nature of "hit and run" workshops. Yet there is recent and compelling evidence that "workshops are the most prevalent form of PD teachers experience across all subjects and grade ranges" (Banilower et al., 2018, p. 75).

Design Principle 2: Learning is Social

As Darling-Hamond & Oakes (2019) suggest, "learning to teach takes place in professional communities in which teachers observe one another, share practices, develop plans together, and solve problems collectively" (p. 123). When teachers work with colleagues and engage in productive dialogue with other teaching professionals they learn from one another, reinforce ideas, challenge one another and grow their practice (Luft & Hewson, 2014). The recent increase in professional learning communities as a teacher learning model is an indication that teachers value collaboration with peers and professional learning providers recognize the value of community (Cuddapah & Clayton, 2011; Wenger, 2010).

Communities of practice (COP) are a common model for professional development of teachers (NCTAF, 1996). They are typically structured as space where educators can share resources and exchange relevant ideas about their practice (Jones et al., 2011). Cuddapah and Clayton (2011) and Wenger (2010) define a community of practice as a social system where participants in a community, dedicated to the domain, negotiate, and renegotiate meaning

through active and social participation with others. In this sense, COPs rely on the theoretical construct of social constructivism (Vygotsky, 1978). Participants in communities support one another through engagement and respectful interaction and they share a common practice. Wenger (2010) states, "A learning partner is not someone who agrees with you or who even shares your background necessarily. It is someone with whom focusing on practice together creates high learning potential" (p.12). COPs rely on individuals coming together around a concern or dedication to something they do and the desire to learn from one another with the goal of doing it better (Wenger-Trayner & Wenger-Trayner, 2015). Professional communities can serve as effective means of supporting teachers into continuing inquiry into practice as they deepen knowledge for-, in- and of- their practice (Cochran-Smith & Lytle, 1999).

Wenger (2010) identified three main components of communities of practice. The domain is the shared interest of the group. It defines the competencies that members of the group have and the knowledge that each will bring to the work. The community defines the members, those who engage in activities together through a mutual commitment to the work. The practice component defines the routines, words, tools, and ways of doing things common to members of the community. When these components are present and well defined, situated learning can support individuals' development.

In the science education community, educators are collaborating to develop practices that support student engagement with phenomena connected to every day, relatable experiences and aligned with the big ideas of science (Windschitl & Calabrese Barton, 2016). For example, the approach to teaching outlined in Ambitious Science Teaching includes a "coherent vision of instruction" (p.1) for rigor and equity and assists teachers with enacting teaching practices that create the learning environments and opportunities for student engagement as described in the

Framework and NGSS. Synthesizing research on highly effective science instruction, Windschitl et al. (2018) offer a practical approach to science teaching centered on four "regularly reoccurring teaching activities devoted to planning for, enacting, or reflecting on instruction" (p.3). The reoccurring teaching activities or practices focus instruction on actions that Windschitl et al. (2018) and colleagues (Stroupe & Gotwals, 2018; Thompson, Hagenah, Kang, et al., 2016; Thompson et al., 2015; Windschitl & Stroupe, 2017; Windschitl et al., 2008, 2011; Windschitl et al., 2012) recognize in making a significant difference for students and allowing science teachers to develop a common language about teaching practices that center student ideas.

Design Principle 3: Teaching is Student-Centered Work

Central to the high-leverage practices movement is the understanding that "student ideas are the raw material of our work" (Beeth & Hewson, 1999; Larkin, 2019) and that all students deserve to share and work on their ideas as learners. I propose an equity frame as a third guidepost for this study. There are many definitions of equity within the field of education. I draw upon the Windschitl and Calabrese Barton (2016) definition of equity for this study, which reads, "providing opportunities for all students to learn challenging ideas, to participate in the characteristic activities of the discipline, and to be valued as important and fully human members of the science learning community" (p. 1101).

This message is consistent with the call for attention to *All Standards, All Students* (NGSS Lead States, 2013) that describes the need for every student to have appropriate opportunities to learn and prepare to be scientifically literate members of society. It is widely agreed that teachers who provide students with opportunities to make meaning of content in the context of their lived experiences are uniquely positioned to boost academic success for students (Thompson, Hagenah, Kang, et al., 2016; Thompson et al., 2013; Villegas et al., 2012;

Windschitl & Calabrese Barton, 2016; Windschitl et al., 2018). For decades, teacher educators have developed an empirical understanding of the importance of culture and identity in education and attention to issues of equity has increased in policy recommendations, from scattered mentions of the need to recognize diversity (NCTAF, 1996) to several specific calls for teachers to "recognize and respond to student diversity and encourage all students to participate fully in science learning" (National Research Council, 1996). The NGSS address diversity and the importance of student culture with unprecedented attention with "*All Standards, All Students."* (NGSS Lead States, 2013). Most recently, the report *What Matter's Now: A New Compact for Teaching and Learning* (NCTAF, 2016) states, "…we continue to struggle with providing access to great teaching and learning for all students. The current education system simply does not work for millions of students, many of them Black and Hispanic students from low-income families" (p.3).

While cultural diversity has gained more emphasis on the pages of policy documents, research shows that teachers need support in learning what equity looks like in the classroom (Bancroft & Nyirenda, 2020; Geneva Gay, 2010a; Johnson, 2011; Larkin, 2019; Riveros et al., 2012). Overall teachers are not entering the classroom prepared to integrate culture into their practice in a meaningful way (Villegas & Lucas, 2002; Zeichner, 2016). Scholars contend that high-leverage practices, developed with equity as a central tenet (McDonald et al., 2013), have the potential to help teachers learn strategies that will "honor students' sensemaking repertoires" (Windschitl et al., 2018, p. 11) and give voice to diverse students to meet the expectation of "help(ing) teachers value the diversity of their students, turning their array of experiences, talents, creativity, skills, grit, and drive into our country's greatest strength" (NCTAF, 2016, p. 5).

Design Principle 4: Teachers are Agents of Change

This study places a great deal of importance on the actions and decisions of individual teachers in their school and classroom contexts, and therefore the concept of teacher agency serves as a useful way to understand how professional development gets enacted. Teacher agency is rooted in social and action-based theoretical approaches to learning (Dewey, 1904/2008) and in knowledge of teachers as "adaptive experts" (Hammerness et al., 2005) and knowledge creators (Cochran-Smith & Lytle, 1999) with "significant within-school influence on school improvement" (Priestley et al., 2015).

As professionals, teachers have the capacity to use their classrooms as spaces for creating "knowledge-of-practice" (Cochran-Smith & Lytle, 1999). Cochran-Smith and Lytle (1999) contend that teachers should be the producers of knowledge, stating "teachers need to treat their own classrooms and schools as sites for intentional investigation at the same time that they treat the knowledge and theory produced by others as generative material for interrogation and interpretation" (p.250). In action-oriented communities, teachers learn and make sense of their work in their local context and in the larger social and cultural context (Cochran-Smith & Lytle, 1999) and they identify problems of practice that they can work on to improve. Teachers can actively identify areas that can be improved as part of their work (Thompson et al., 2015). Hammerness et al. (2005) state "the way people initially frame problems has major effects on their solution strategies because different framings open up different 'problem spaces' for people to explore" (p.360). They recognize professional teachers as capable of efficiently and effectively applying techniques and continually innovating to rethink practices and reflect on what they do as teachers.

Teacher agency is action oriented and takes place in social, collaborative, and "culturally-imbued" spaces (Eteläpelto et al., 2013, p. 66). While arguably not well conceptualized in the literature (Biesta et al., 2015; Priestley et al., 2015), teacher agency is consistently described as action that individuals take within a teaching context. Scholars differ on the extent to which individual identities and experiences play a role in teacher agency, a nuance that distinguishes the subject-centered, socio-cultural perspective (Eteläpelto et al., 2013) from the ecological view (Biesta et al., 2015; Priestley et al., 2015). The socio-cultural perspective of teacher agency centers the individual and their negotiation of identity as professionals in the social process of learning. Adult learners are thought of as:

> Individuals who not only learn the new knowledge and skills needed in their work, but also act as feeling and willing subjects who actively prioritize, choose, and consider what is important and worth aspiring in their life and future, and thus practice agency in their life (Eteläpelto et al., 2013, p. 62).

Individuals bring their personal selves, their identity to the "human-centered" and "emotional" work of teaching (Eteläpelto et al., 2013). However, the degree to which an individual can have agency is disputed. Biesta et al. (2015) suggest an ecological view to agency that requires engagement with "temporal-relational contexts-for-action" and is not dependent on the "quality of actors themselves" (p.626). Similarly, Priestley et al. (2015) argue that agency is always informed by past experience, it is always orientated towards short and long term goals in the future, and values. Agency is constrained and supported by the context, "enacted in a concrete situation" (p. 4). The ecological view conceptualizes agency not as something that people have, but rather something that people do and achieve in context (Priestley et al., 2015).

Pantić (2017) explores teacher agency for social justice by grounding her case study work with elementary teachers in an ecological view of agency, described as dependent on a teacher's:

- *Sense of purpose*: belief that a certain practice is worthwhile for achieving a certain outcome.
- *Competence*: knowing how to influence a desired outcome in practice,
- *Scope of autonomy*: power to make a difference within given structural environments, and,
- *Reflexivity*: a capacity to monitor and evaluate one's actions and structural contexts. (p.220).

Despite the nuanced discussion around subject-centered or ecological conceptualization of teacher agency, the construct is consistently employed as an explanatory tool for developing teacher practice and supporting teacher learning. Teachers, as learners, engage in the construction of knowledge through metacognitive processes, reflection on their practice, problem identification, and problem solving (Eteläpelto et al., 2013).

The design of this study draws on the four principles described above and take a practice-focused approach to professional learning. Through this lens teachers are both the objects of knowledge and the creators of knowledge as they identify, work on and plan to enact shifts in their teaching of science and engineering practices through an equity lens.

Practice-focused Teacher Development

Recent work in teacher education and teacher development has taken on a practice focus, recalibrating the core components of the profession to include a greater emphasis on pedagogy, while maintaining the importance of content knowledge. Scholars call for a "shift from a focus on what teachers know and believe to a greater focus on what teachers do" (Ball & Forzani,

2009). Broadly across teacher education and more narrowly within disciplinary fields, teachers and teacher educators are working collaboratively to identify a set of "teaching practices that involve knowledge and doing" (Cohen, 2015; McDonald et al., 2013) and can serve as a common language to be referred to across the professional continuum (Stroupe & Gotwals, 2018; Thompson, Hagenah, Hosun, et al., 2016; Thompson et al., 2015). The goal of developing "high-leverage" practices is rooted in the need to bridge research on teaching with the work of teacher educators. McDonald et al. (2013) contend that a practice focus has the potential to help the field in three specific ways:

- Articulate a common language for specifying practice, which would facilitate the field's ability to engage in collective activity
- Identify and specify common pedagogies in teacher education
- Address the perennial and persistent divides among university courses and between university course work and clinical experiences (p. 379).

Research focused on teacher practice provides insight into the specific moves and teaching tools that assist teachers in facilitating the deep learning called for in reform documents (Cohen, 2015; Desimone et al., 2013; McDonald et al., 2013; Windschitl et al., 2012). These practices include knowledge of content and knowledge of actions that allow teachers to develop skills necessary to engage in the "in the moment decision making" required to teach (McDonald et al., 2013).

A practice focus centers student ideas and includes strategies that elicit student ideas so that communities of learners can work on and develop their understanding (Beeth & Hewson, 1999; Larkin, 2019; McDonald et al., 2013; Windschitl et al., 2018). Orienting teachers towards actions and decisions that they make in the classroom requires providing teachers with

opportunities to question their practice and work on pedagogies that center students' ideas in the work of teaching. Positioning student ideas as powerful and valuable in the classroom is widely supported in learning theory (Dewey, 1904/2008; Vygotsky, 1978), however, poorly executed in practice (Liu & Ball, 2019; Zeichner, 2016). The transfer of practice from preparation and development programs to the classroom can be a challenge and even when teachers prepare to teach with a practice focus, the enactment of those practices in the classroom may look very different.

Kennedy (1999) refers to this phenomenon as the "problem of enactment," a phrase used to describe circumstances where teachers learn to teach in one way but enact a different method with a lack of awareness that they are doing so. While Kennedy (1999) first used this term to describe preservice teachers, Kennedy (2016) also applies the idea to the development of in-service teachers. When a new and different idea about teaching is introduced to teachers there can be a disconnect between current conceptions of their work and enactment of the new idea. This lack of coherence can have a significant influence on how teachers take up new teaching practices (Kennedy, 2016; Kloser et al., 2019; Penuel et al., 2014). Kennedy (2016) states,

> For teachers, enacting a new idea is not a matter of simple adoption but rather a matter of figuring out whether, when, and how to incorporate that new idea into an ongoing system of practice which is already satisfactory, and may also be largely habitual (p. 11).

Berland et al. (2016) argue that teachers will take up scientific practices when they understand them to be meaningful to the scientific community and meaningful to the teaching and learning of science. Teachers can develop understanding, what Kennedy (2016) describes as the "ah-ha" moment, when teachers gain insight into the reason behind the change. Insight and the decision that follows about the degree to which teachers take up new practices is also

influenced by social, professional, personal and context specific dynamics (Colburn 2001; Spillane 1998). Given the difficultly of implementing reform-based practices in classrooms (Elmore, 2004), it is important to provide opportunities for teachers to engage in the practices of science with other professionals and share their thinking, knowledge, "failures" and "successes" with a community of professionals (Bryk et al., 2015; Kloser et al., 2019; Loucks-Horsley et al., 2009; Thompson et al., 2015).

The focus on high-leverage practices addresses the problem of enactment by drawing attention to specific components of teachers' practice that are essential to the work (McDonald et al., 2013). McDonald et al. (2013) claim that the high-leverage practices approach "push(es) against the tendency in teacher education to default to an acquisition model of learning" (p.381). A coherent vision of science practices will support beginning teachers enactment of learned teaching moves and serve as a foundation for contextual adaptation to practices based on teachers' knowledge of students (Windschitl et al., 2018). Ideally a coherent message of how teachers should help student make sense of content will diminish the problem of enactment and allow for scholars and practitioners to collectively iterate on practices that best serve student learning.

Ambitious Science Teaching

Within the discipline of science education, scholars suggest specific teaching practices that respond to the needs established within the high leverage practice scholarship. Ambitious Science Teaching (AST) is an approach specific to science teaching that offers a set of rigorous and equitable teaching moves grounded in research on how diverse students learn science (Windschitl & Calabrese Barton, 2016). The approach to teaching outlined through AST high leverage practices is specific to science education and responds to the call to establish a

"coherent vision of instruction" grounded in rigorous and equity-focused teaching (Windschitl et al., 2018, p. 1). Synthesizing research on highly effective science instruction, Windschitl et al. (2018) offer a practical approach to science teaching centered on four "regularly reoccurring teaching activities devoted to planning for, enacting, or reflecting on instruction" (p.3). The practices focus instruction on actions that Windschitl et al. (2018) and colleagues (Stroupe & Gotwals, 2018; Thompson, Hagenah, Kang, et al., 2016; Thompson et al., 2015; Windschitl & Stroupe, 2017; Windschitl et al., 2008, 2011; Windschitl et al., 2012) recognize in making a significant difference for students and allowing science teachers to develop a common language about teaching practices.

The first practice, *Planning for Engagement with Big Ideas*, guides teachers to identify and select big ideas in science to focus instruction with strong consideration of student's interests, local community, and culture. The second practice, *Eliciting Student Ideas* hold students' ideas as central to the learning process and invites students to share what they know about a topic. In this way student ideas are treated as valuable resources in the learning process. The third practice, *Supporting Ongoing Changes in Students' Thinking,* includes criteria for activities that allow students to engage in sensemaking where they demonstrate understanding of an idea and can use their understanding to explain a phenomenon. Teachers use practices such as questioning, summary tables, supporting ideas with evidence, and others throughout teaching to encourage peer to peer talk that facilitates sensemaking. The fourth practice set, *Drawing Together Evidence-Based Explanations* describes teacher moves that help students "pull together different ideas and bodies of evidence in order to advance their current explanations and models" (p. 215). Students revise their models and demonstrate understanding with of a checklist of items that guide explanations of the science ideas underlying the anchoring phenomena and work through

their answer to the essential question. Ultimately, students' revised model provides evidence that they have a "gapless explanation" of the science content (Windschitl et al., 2018).

Teaching with AST practices can be very different from the methods with which teachers are accustomed (Cherbow et al., 2018; Windschitl & Calabrese Barton, 2016; Windschitl et al., 2011). Teacher educators and teachers are working collaboratively in specific settings to support changes in instructional practices based on AST (Larkin & Woodruff, 2019). Most of the work is taking place in university-based teacher education programs where pre-service teachers are placed with mentor teachers and both develop capacity for AST through a supportive and collaborative structure (Stroupe & Gotwals, 2018; Thompson et al., 2015)**.** Windschitl et al. (2018) encourage teachers to take up the work within teacher-driven teams, such as professional learning communities in schools who gather regularly to work on improving instruction and "share risks and challenges of innovation with colleagues" (Windschitl et al., 2018, p. 237). While the authors of the AST framework provide examples of their direct work with teachers engaged in improvement communities, little is known about how AST is being integrated into existing structures of professional development or how teachers are taking up practices in their everyday teaching. One contribution of this study was to consider the use of high leverage practices, such as those proposed in the AST approach to support teachers in centering students as equity practice. The practice focus of this work became important for addressing the research questions.

Purpose of Study and Research Questions

The purpose of this study is to understand how teachers make sense of equity and agency in a professional learning experience aligned to research-based practices. The work draws upon understandings about practice-focused teacher learning in order to investigate the ways in which

teachers make sense of ideas about equity when teaching the science and engineering practices as described in the NGSS. Ten teachers from ten different schools, all located in two neighboring states, engaged in a community of practice, facilitated by me, as the researcher. Seven of the ten teachers are highlighted in this research. The study, spanning a 16-week period, included ten online meetings, a pre and post interview, and individual time to select a problem of practice and then decide how to translate feedback from the group into practice. As the facilitator, I bounded the work by requesting that problems of practice be aligned to equity and to at least one of the SEPs. The specific research questions that guided this work are:

1. How do teachers make sense of equity through negotiations with peers in a professional community of practice?
2. How do participants translate their ideas about equity in planning for enactment?
3. To what extent are "science and engineering practices" and "equity" related components of teachers' practice?

As will be detailed in the following chapter, this study draws upon sensemaking theory as a conceptual framework (Weick et al., 2005), by examining teachers' dialogue with one another, sharing of resources, and translation of ideas in their planning for classroom teaching. Sensemaking is a commonly used theoretical framework for studying the way that individuals describe and make meaning of the unknown, an explanatory tool for this inquiry.

Significance of the Study

This study is significant because it responds to the call for teachers to take up the work of improving instruction in collaborative spaces where they can share risks and explore innovations in their teaching for the benefit of their students (Windschitl et al., 2018). Much of the work being done to promote equity and to gain understanding about the use of high leverage practices

in teaching is occurring in pre-service teacher education programs. Here, in-service teachers volunteer to engage in this work to improve their practice. The design of the study provided participants with the opportunity to engage with other professionals and work on critical aspects of their teaching with the goal of becoming more equity focused.

This study positions teachers both as knowledgeable and as creators of knowledge, recognizing their valuable insights about students and their dedication to improving their practice. Like other critical professional development opportunities, the community of practice work took place outside of teachers' contexts, on their own time, and separate from administrative school-based oversight. Teachers engaged in productive dialogue and pushed one another to progress in their thinking about equity focused teaching practices. They learned from one another as equal professionals and progressed in the ongoing journey of improving their practice. The model serves as a scalable option for supporting in-service teachers and the outcomes lend to understanding of how teachers make sense of equity when teaching the SEPs.

Chapter Two: Theoretical Framework & Literature Review

In this section I justify the use of sensemaking as the theoretical framework for the study and situate the work within the body of literature on professional learning of the science and engineering practices and professional learning of equity practices.

Sensemaking as a Theoretical Framework

The challenge of implementing reform-based practices in classrooms requires an understanding of how teachers negotiate the messages they receive about teaching practices (Allen & Penuel, 2015; Coburn, 2001; Thompson et al., 2015). I draw on the theoretical framework of sensemaking to understand the ways that teachers identify important aspects of their teaching to work on, grapple with new ideas and inconsistencies, and decide how to proceed. When applied to issues of equity, sensemaking theory serves as an explanatory framework for understanding how teachers identify and foster opportunities for all students to engage in authentic science (Allen & Penuel, 2015; Weick et al., 2005). These questions guide the work of identifying the phenomena that require attention and working through a process of figuring out what to do about it. Education researchers employ sensemaking theory to understand how teachers respond to new policies, programs, and initiatives (Coburn, 2001; Kloser et al., 2019; Weick et al., 2005).

The primary characteristic of sensemaking consistent in the literature is that it is a social and collaborative process where teachers negotiate meaning through establishing their own identity and by interacting with colleagues. Allen and Penuel (2015) state that teachers engage in sensemaking using their “practical knowledge”, the information they call upon regularly to plan for and enact teaching, including the various challenges of their daily tasks. Practical knowledge may either help them when making sense of new ideas and concepts during professional

development or inhibit changes. Teachers' practical knowledge is also embedded in their teaching context, including interaction with peers. Through discourse opportunities teachers can engage in rational decision making. They may not reach total consensus, but the process of collecting evidence, discussing ideas and implications, and trying out new strategies leads to new actions that are supported by meaning making. It is well established in science education literature that teachers need time for engaging in reform practices and grappling with how those experiences translate into classroom teaching (Banilower et al., 2018; Loucks-Horsley et al., 2009).

A second distinction of sensemaking is its orientation towards action which begins with organizing and interpreting some level of uncertainty. Those engaged in the process identify a phenomenon that requires attention, learn about it, communicate, and reflect in discourse environments, and identify what to do next. The exchanges that take place between individuals, and the decisions that follow are intended to disrupt a system where change is necessary. In the case of science education reform, the "new event" may be new standards or new high-leverage practices that are focused on student thinking. Before teachers implement shifts in their practice to address this concern, they engage in some form of questioning and trying to make sense of what is new.

When used as a framework for learning about a teacher's process for making meaning of reform based practices, scholars are able to better understand teachers' ability to interpret the reform from each teacher's specific position. Allen and Penuel (2015) focused on three different teachers, participants in a professional development on reform-based teaching practices, who were located in three unique school settings. The researchers questioned the source of ambiguities and uncertainties that teachers had at various stages by exploring their sensemaking

strategies. They found that in each context teachers had to resolve ambiguities about coherence of reform to their district specific policies and department specific expectations. They found that teachers choose to move towards reform teaching strategies as a result of the professional development experience. Allen and Penuel (2015) concluded that the sensemaking process and the supports that teacher's used to engage in action-oriented learning opportunities were an important component for effectively supporting change in their study.

Second, sensemaking is a useful lens for understanding the construct of teacher agency and how perceived agency, or lack of agency, impacts teachers' ability to enact shifts in their teaching practices. Agency is an important component of the design of the professional development model in this study and analysis of data through this lens highlights how teachers engage in construction of new knowledge when working on problems of practice that they deem important in their teaching. Through the lens of agency, I sought to understand how teachers decided to enact practices in their teaching and the extent to which there were barriers that prevent them from using their professional knowledge (Biesta et al., 2015; Eteläpelto et al., 2013; Pantić, 2017; Priestley et al., 2015).

Sensemaking is a useful lens for understanding the organizational process of how teachers learn about new ideas, in this case equity in their NGSS focused classrooms, and what they decide to do with the information. As a model for teacher learning, it is important to understand how this work fits into the existing literature and addresses gaps in understanding how teachers make sense of equity in their teaching.

Literature Review

This study is situated amid two specific strands in the field of teacher professional development: teacher learning of science and engineering practices, and teacher learning of

equity practices. In the following pages, I review empirical literature in each of these strands to locate my inquiry in the field.

Science and Engineering Practice Focused Professional Learning

Reiser (2013) suggests that professional development for NGSS must be structured as collaborative efforts for applying NGSS, citing collaboration as "a key element to the active sensemaking identified as needed to understand the reform" (p. 16). In this chapter, I provide a comprehensive review of the literature on professional development programs that focus on the NGSS SEPs, through a search of all EBSCO Host databases available in the Montclair State University library system. I conducted an initial search using keyword terms "next generation science standards," "professional development," and "practices". I conducted a second search using keyword terms "science and engineering practices," "professional development," and "community of practice." After eliminating duplicate results, I reviewed 172 abstracts.

Recognizing that teachers need direct experience with reform practices (Penuel et al., 2007) and that professional development activities should be focused on classroom activities that ensure coherence between professional development activities and enacted practice (Garet et al., 2001), I chose to focus this review of the literature on how programs support teachers active learning and direct engagement with SEPs. Consistent with Wilson (2013) recognition that professional development programs exist in myriad forms, literature reviewed here represents a wide array of designs, including short duration, two to six day workshops (Antink-Meyer & Arias, 2020; Danielson & Matson, 2018; Merritt et al., 2018; Utley et al., 2019), and programs that integrate brief workshops, after school meetings, and summer camp experiences (Dailey et al., 2018; Douglas et al., 2016). Several studies include programs that span two years or more and make use of summer institutes (Hayes et al., 2019; Kang et al., 2019; Lesseig et al., 2016),

integrate in class coaching (Kang et al., 2019), and collaboration with professional scientists and engineers (Kolikant et al., 2006). Within this strand of the review, I identified four main themes: 1) Developing Practices with Exemplars, 2) Learning Through Implementation and Observation, 3) Practices that Center Student Ideas and Cultural Knowledge, 4) Challenges to Integrating the Science and Engineering Practices.

Developing Practices with Exemplars. Professional developers and facilitators often use model curriculum to demonstrate well-aligned units and exemplify what the SEPs look like in the classroom. For example, the authors of three studies report use of the Boston Museum of Science curriculum, *Engineering is Elementary* (EiE) to demonstrate well-aligned lessons (Dailey et al., 2018; Guzey et al., 2014; Utley et al., 2019). This model curriculum is developed by museum-based curriculum writers and focuses primarily on the engineering components of the SEPs. Cunningham and Carlsen (2014a) recommend professional development that supported teacher's engagement with engineering design, stating teachers "don't readily learn the practices or how to teach them by reading or watching others engage−they have to dive in. This usually includes an engineering design challenge so the work actually models the cycle of design" (Cunningham & Carlsen, 2014a, p. 204). The authors of the three EIE focused studies recognize that modeling engineering pedagogies supports teachers' shift away from the quest for the right answer towards a mindset that "failure is an option" (Cunningham & Carlsen, 2014a, p. 205). Based on these studies effective professional development encourages teachers to experience engineering both as learners and as teachers.

Dailey et al. (2018) use EiE units as part of the *STEMulate Engineering Academy*, a professional learning experience designed to give teachers direct experience with implementing EiE units with the goal of implementing them in the classroom. Working over a period of two-

years, 16 grade three to five teachers and facilitators worked with students in a summer camp. Prior to the camp, teachers attended a six-hour workshop focused on differentiating instruction to diverse learners. Then, teachers learned along with students as facilitators modeled instruction. In year two of the program teachers created their own "student-centered, differentiated, and developmentally appropriate STEM-based unit that centered on the engineering design process" (p. 101). Researchers found that teachers demonstrated statistically significant improvement in their attitude and comfort level with teaching engineering after the first year. They concluded that the professional learning model "addressed the critical elements of professional development by providing teachers opportunities for extended contact time and specific training on the curriculum and content and by engaging teachers in active learning" (p. 104).

In a similar model, Guzey et al. (2014) describes a one year professional development including thirty-six teachers of students in grades three through six. Participants engaged in five workshop days focused on specific model units from EiE and other exemplary curriculum and held professional learning community meetings in between. Teachers learned the units and then elected to either use them in their teaching or develop their own lessons, often adapted from online sources. Teachers shared classroom implementation of engineering lessons in culminating poster sessions, which researchers analyzed for evidence of quality engineering activities. They categorized the lessons as one of the following: "complete; design-focused without a realistic context; design-focused without redesign; build and test only; and misapplication" (p.144). The purpose of this categorization was to identify how teachers incorporated what researchers determined to be essential components of engineering design into their teaching. For example, they stated "the use of a realistic context is critical in order to place engineering problems into a situation explaining why students or engineers might need to solve similar problems" (p. 147).

Guzey et al. (2014) concluded that all participants successfully integrated engineering into their teaching and the majority were "complete," suggesting that the use of the model curriculum supported professional development goals. However, the finding that some lessons lacked essential components of engineering practices indicated that the teachers needed continued support to fully implement the SEPs.

Lesseig et al. (2016) reported on a two and a half year *Math Science Partnership* for middle school teachers including two, weeklong summer professional development institutes. Teachers engaged in design challenges aligned to NGSS standards, including the design of a prosthetic limb and a challenge to use robotics to colonize Mars. Like Dailey et al. (2018), the professional development experience included teachers working with students for part of the day and then reflecting on their teaching. Researchers noted that over time the teachers became more engaged and dedicated to the design challenges. Data analysis showed that teachers valued the use of engineering to increase "student attainment and use of scientific, mathematical, and engineering (SME) practices and motivation, engagement, and empowerment by all learners" (p. 181). Teachers recognized design challenges as pedagogy for engaging students in authentic problem solving where they did their own research and problem solving. Notably, researchers emphasized that participants frequently commented on "the need to create a culture of inquiry to give the students a reason beyond fun for design" (p. 181).

Teachers participating in professional development provided by California Environmental Education Foundation used lessons from *Project WET, Project Learning Tree,* and *Project Aquatic WILD* as foundation for implementing class stewardship projects focused on caring for the environment (Hayes et al., 2019). Hayes et al. (2019) report on twenty-eight teachers from three urban schools with grade ranges from elementary to high school, as they

demonstrated planning and implementation of lessons aligned to NGSS SEPs. Researchers report that using the curriculum as a starting point helped teachers shift conceptions about strategies, tools, and activities for student-centered teaching aligned to the SEPs. Student enthusiasm inspired teachers to use environmental topics as contexts for integrated teaching. One teacher addressed the challenge of integrating engineering design given time constraints, stating "the biggest hurdle is getting over the idea that you have limited time to teach the way you want" and identifying stewardship projects as "the cornerstone of NGSS and CCSS" (p.128). In this case, teachers overcame recognized barriers to the SEPs and identified ways to align teaching to SEPs within their school structure because they believed in the meaningful connections that the activities made to students' everyday lives.

Often collaborative spaces exist through university partnerships and programs that center teacher learning (Antink-Meyer & Arias, 2020; Lehman et al., 2014). Lehman et al. (2014) brought together ten university faculty members and 40 elementary school teachers to implement lessons developed by university faculty members. Throughout the project, faculty members and teachers met regularly to discuss the lessons, collaborate with one another, and in some cases co-teach lessons. The collaborative approach from faculty members was the most widely cited factor contributing to the success of the lesson design and implementation. Teachers responded favorably to the support provided and one participant shared praise for the "already made lesson plans that can be tweaked to fit my curriculum" (p. 25). Similarly, Antink-Meyer and Arias (2020) report that the 30 teachers participating in a university course where teachers engaged in a design challenge on the science of sound, benefitted from the process of "contextualizing the learning standards and practices" and "unpacking the standards" (p. 58) in collaborative teams.

These studies suggest that by using model curriculum as a starting point, teachers can focus on the student centered implementation of the curriculum, rather than both the creation and implementation of lessons (Williams et al., 2019). Contextual factors determined the extent to which teachers were able to modify curriculum and be responsive to student's needs. However, when teachers see meaningful connections between student's lives and curriculum, they can be inspired to overcome perceived boundaries. As educators and administrators learn to enact NGSS based teaching practices, administrative oversight is an important factor for teachers. In this study I consider the role of administrators as a factor that influence teacher's autonomy to make decisions about enacting practices that center student experience as a component of equity pedagogy.

Learning Through Implementation and Observation. Methodologically, observation of teachers implementing lessons and learned practices serves as a valuable research tool. Researchers can systematically collect data and notice specific instances in the classroom that may not be observed through other means. Observation allows the researcher to record behavior as it is happening, or in the case of video recordings, refer repeatedly to behaviors as needed to learn from them. Merriam and Tisdell (2016) recognize observation as a particularly helpful tool for "understanding ill-defined phenomena (p. 139), such as how to implement SEPs and other reform strategies in classrooms (Windschitl, 2003).

Lesseig et al. (2016) and Hayes et al. (2019) work suggests that teachers are inspired to spend time and effort integrating SEP practices when they experience success and recognize enthusiasm with students engaged in the practices of science and engineering. When working in collaborative groups teachers can learn to build meaningful opportunities for SEPs that emphasize student experiences that are "authentic rather than contrived or forced into classroom

instruction" (Nagle & Pecore, 2019, p. 8). Video and observation allow researchers to recognize what works in classrooms and in professional development sessions. As researchers and facilitators continue to iterate on research-based practices for professional development models, these findings are valuable.

The in-the-moment decision making that is central to responsive instruction requires that teachers be thoughtful and make changes to their instruction sometimes on the fly, without rehearsal. In a study with teachers using exemplar curriculum from Investigating and Questioning our World through Science and Technology (IQWST) (Krajcik, 2013), researchers reviewed video of middle school teachers to learn from their teaching practices. Ko and Krist (2019) determined that teachers who "open up aspects of the curriculum materials to student decision making" allow students opportunities to take "intellectual ownership over their engagement in scientific practices" (p. 990). As a result, students made connections to their experiences with families, communities, and cultures. The students offered examples and ideas from outside the curriculum and beyond the classroom, and even identified with the teacher when it might be time to move on. The nuanced work of making space for students' ideas and the instances when students took ownership for themselves, described as epistemic agency, was captured, and reviewed using observation tools.

Similarly, Kang et al. (2019); Williams et al. (2019) and Merritt et al. (2018) used video observation to help teachers improve their practice. Williams et al. (2019) reported on teachers' enactment of the INSPIRES curriculum and were able to identify areas where teachers needed to hone their practice such as when connecting design challenges to content and building on student ideas in a lesson. Working with elementary teachers, Merritt et al. (2018) coded teacher practice with each of the SEPs to analyze teachers attention to each and used video to make specific

observations that led to discussion about questioning strategies that supported student driven scientific investigation. Using an observation tool aligned to grade level bands from the NGSS, Kang et al. (2019) identified the practices that teachers most commonly enacted and those with which they might need support. Observation allowed researchers to collect data on both teacher and student successes and challenges and use the data to inform professional development activities. Findings indicate that teachers showed a "marked increase in the number of practices and student-enacted practices from time one to time two observations" (p.22). They attribute the success to the highly responsive and collaborative nature of the professional development design. The practice of using structured tools to rehearse teaching and improve skills is common across the studies reviewed above.

Practices that Center Student Ideas and Cultural Knowledge. Existing literature focused on how teachers center student ideas and cultural knowledge serves as an important basis for this study. As discussed in Chapter One, current reform language calls for student-focused practices but the enactment of teaching that intentional centers students and their cultural knowledge is not well understood. The following studies provide insight into contexts where teachers who enact equity practices succeeded in centering student ideas and cultural knowledge. This literature also suggests gaps in our understanding of how teachers attend to cultural knowledge.

Haag and Megowan (2015) suggest that teachers who used specific student-centered practices in their teaching prior to NGSS were better equipped to integrate the SEPs. Analyzing survey results from 710 teachers in 38 states, Haag and Megowan (2015) assert that teachers who

had experience with modeling instruction[1] prior to NGSS were more comfortable with implementing SEPs. They attribute this finding to the emphasis that modeling instruction places on the active learning of science and argue that the eight-core science and engineering practices and modeling pedagogy are built upon the same foundation of "conceptual representation of a real thing" (p. 418). This approach has been taken up by teachers nationally and integrated into classroom teaching for decades (Larkin & Woodruff, 2019). Student's ideas are represented through diagrams, cycles, maps, and other visuals that show conceptual thinking.

Modeling as a practice is central to Ambitious Science Teaching (AST), an approach that offers a core set of rigorous and equitable teaching moves grounded in research on how diverse students learn science (Windschitl & Calabrese Barton, 2016). Through four regularly reoccurring teaching activities structured around planning for, enacting, and reflecting on instruction, teachers build conceptual understanding by starting with their students' ideas. Teaching with AST practices can be very different from the methods with which teachers are accustomed (Cherbow et al., 2018; Windschitl & Calabrese Barton, 2016; Windschitl et al., 2011). Teacher educators and teachers are working collaboratively in specific settings to support changes in instructional practices based on AST (Larkin & Woodruff, 2019). Most of the work is taking place in university-based teacher education programs where pre-service teachers are placed with mentor teachers and both develop capacity for AST through a supportive and collaborative structure (Stroupe & Gotwals, 2018; Thompson et al., 2015)**.** Windschitl et al. (2018) encourage teachers to take up the work within teacher-driven teams, such as professional

[1] Modeling instruction is an approach to teaching described by Wells, M., Hestenes, D., & Swackhamer, G. (1995). A modeling method for high school physics instruction. *American journal of physics, 63*(7), 606-619. https://doi.org/https://doi.org/10.1119/1.17849 and Hestenes, D. (1987). Toward a modeling theory of physics instruction. *American journal of physics, 55*(5), 440-454. https://doi.org/https://doi.org/10.1119/1.15129

learning communities in schools who gather regularly to work on improving instruction and "share risks and challenges of innovation with colleagues" (p. 237). While the authors of the AST framework provide examples of their direct work with teachers engaged in improvement communities, few studies define how AST is being integrated into existing structures of professional development for in-service teachers, a contribution that this study will make to the literature.

Thompson et al. (2015) worked with novice and mentor teachers to understand how each party framed or made sense of opportunities to improve teaching. Researchers designed a week-long summer program for teachers to learn about ambitious teaching practices and supported teachers throughout the school year through regular meetings and online groups. Teachers posed questions and received support from peers and university-based science coaches. Throughout the study the researcher's studied how novice and mentor teachers worked on problems of practice. They concluded that some dialogue was more productive than others and suggested that focusing on productive challenges, which they refer to as "problems without ceilings" supported teacher development. Thompson et al.'s (2015) mentor-novice model provided a unique and effective strategy for professional development.

Learning to center student ideas includes inviting community and culture into the learning process. Teachers can provide students opportunity to leverage the expertise in their communities as they engage with SEPs. Through a community ethnography approach, Schenkel et al. (2020) detailed how students can take a stance on an issue that is important to them to define problems and design solutions. Teachers can enact practices that make space for students to engage with each other and with cultural referents in the community. This student-centered, community-centered approach gives students agency in their learning so that they are *doing* the

science and engineering and they are addressing interdisciplinary issues that have the potential to improve the communities in which they live.

In a recent study with secondary teachers, Hagenah and Thompson (2021) sought to understand how teachers were responsive to students' lived experiences, their ways of living, and their science ideas and studied the way in which teachers made pedagogical choices about using students' science ideas in their practice. They found that the three teachers they studied enacted practices in different ways, in response to their student's needs. Through attention to students' lived experiences as the context for scientific phenomenon, they found that there were more opportunities for students to build understanding through the use of everyday lives and experiences. Hagenah and Thompson (2021) suggested that teacher responses to students' ideas in the moment matter to maintain connections to students lives and the ability for teachers to plan and enact responsive teaching practices is influenced by contextual supports and collaboration with other teachers. This study serves as a recent example of support for in-service teachers, research that I seek to build upon with this study.

Isolated examples of research-practice partnerships and pre-service teacher education programs where educators and researchers seek to understand what centering student ideas and cultural knowledge looks like in practice contribute to the knowledge base for critical work in teacher education. However, there is a dearth of research on how to support teachers who are presently in classrooms and require support in unlearning oppressive pedagogies and taking up practices that examine social and cultural connections in their teaching. The findings presented in this study contribute to understanding how teacher's use specific practices to center students' ideas.

Challenges to Integrating the Science and Engineering Practices. Studies that identify barriers to learning and implementation of SEPs contribute to knowledge of challenges that professional development providers, schools, and teachers can address moving forward. Programs that were not successful in supporting teachers with learning and implementing, which is often the measure of successful learning, often highlight missing components of professional development that align with known practices. For example, Loucks-Horsley et al. (2009) state "effective professional development experiences support teachers to work with colleagues and other experts in learning communities to continually enhance their practice" (p. 71). It is clear throughout the literature on professional development that collaboration is essential (Archibald et al., 2011; Darling-Hammond et al., 2011; Desimone, 2009; Garet et al., 2001). Whether collaboration takes place in small groups or in larger professional learning communities, the key component of success is the ability to make sense of ideas over time. Programs that lack collaboration often fall short of reaching their goals.

For example, Douglas et al. (2016) explored contextual factors that led to varying approaches to engineering design in two different schools. Through a mixed methods case study analysis, they reviewed the factors in each school to determine that only one of the schools was able to sustain engineering pedagogy. Researchers found that teachers and students at both schools showed great enthusiasm for engineering design in the classroom, but teachers at one school were able to integrate engineering practices long term while the other was not. Researchers attributed the difference primarily to the collaborative approach adopted by the school that was able to integrate engineering into the existing curriculum. Teachers used co-teaching methods to support one another as they gained comfort with model curriculum and found "creative ways to integrate engineering into other subjects as a way of meeting district

curriculum standards" (p.330). The other school cited contextual challenges, such as departmentalization, as a barrier to integrating engineering. Teachers stated that functioning with teachers who were specialized by subject created planning and implementation challenges that they could not overcome, therefore they did not use engineering beyond the professional development. This study supports Archibald et al. (2011) suggestion that professional development will be most successful when paired with curriculum standards. For sustained change to take place, there must be a coherent plan and commitment from teachers and administrators and implemented in a collaborative environment that includes administrative support (Bryk et al., 2015).

Despite successes reported by Guzey et al. (2014), discussed above, the researchers determined that time constraints often led teachers in the professional development to skip the redesign component of a challenge and that some subject areas lacked good engineering connections, making it less likely for some teachers to integrate engineering. Hammack and Ivey (2019) found that elementary teachers see time as a barrier to integration of engineering design, based on the results of a survey of 542 teachers in Oklahoma. Blanchard et al. (2013) also found time to be a constraint to engineering design, although the 977 teachers in North Carolina who responded to their survey indicated that time was specifically related to lack of planning time and lack of resources.

Teachers involved in the PD described by Lesseig et al. (2016) were able to successfully integrate new practices into their teaching. However, they reported barriers that had to be overcome. First, they cited the challenges of activities not directly aligning to grade level standards. Teachers reported that their scope and sequence was "inflexible," and researchers noted this as a structural challenge, specifically in the math curriculum. The particular group of

teachers in this study were able to work around the structural issues that they felt they could not change by coordinating "whole-school DCs (design challenges) that all students at a particular grade level would complete on specific days" (p. 184). Lessig et al. (2016) substantiated findings of other studies by recognizing the complexities of implementing science and engineering practices in traditional school structures, specifically those practices that seek to integrate across subject areas.

Overall, review of literature on professional development intended to assist teachers with implementation of SEPs supports the National Research Council (2009) claim that professional development must allow teacher to "come away with in-depth understanding of the purpose of the materials and first-hand experience with some of the difficulties and successes students might encounter" (p. 103). Literature suggests that professional development programs can support teacher's confidence, pedagogical knowledge, and access to resources that lead to sustained attention the SEPs. However, concerns about time, administrative support, lack of collaboration, and restrictive curriculum, must be addressed. Teachers are most successful when positioned as knowledgeable professionals ready to meet the task of doing science and engineering with students so that they develop a deeper understanding of concepts.

Equity Focused Professional Learning for Science Teachers

Teachers benefit from preparation and professional development to recognize inequities, grapple with their beliefs and practices, and develop dispositions that result in the enactment of practices based on beliefs that all students have cultural funds of knowledge that can be leveraged to develop deeper understanding of content (Ball, 2009; Kohli et al., 2015; Larkin, 2019; Moll et al., 1992; Windschitl et al., 2018). While teachers may state their dedication to support all students access to learning, the enactment of their beliefs are not as straightforward

(Kennedy, 2016; Rosebery et al., 2016). It is possible to agree with the doctrine of education for all, as represented throughout many reform documents and reports, and not be able to translate those beliefs to classroom practice (Liu & Ball, 2019).

A review of literature targeting professional development programs that are specifically designed to support teachers' attention to equity provides a view of the varied, yet limited work done in the field to date. I conducted a search of the Education Research Complete database, using terms “equity,” “professional development” and “science teaching” which resulted in the review of abstracts for 40 peer reviewed papers. Studies that focus on equity are commonly tagged with the term culturally responsive pedagogy, therefore I conducted a second search using “culturally responsive pedagogy,” “science education,” and “professional development.” After removing duplicate results, I reviewed 67 studies describing in-service professional development programs in science education.

All studies included program design that engaged teachers in active improvement of practice. The professional development approaches represented in the literature include the use of collaborative groups focused on lesson planning (Cunningham & Carlsen, 2014b; Fickel, 2005; Johnson, 2011), guided reflection for noticing the role of language and culture (Hudley & Mallinson, 2017; Lodge, 2017), design and implementation of action research in classrooms (Alvaré, 2017; Brenner et al., 2016), and close reflection of practice using tools such as video (Minchew Deaton et al., 2014; Rosebery et al., 2016). Some studies included work in indigenous communities (Alvaré, 2017; J. Nam et al., 2013; Y. Nam et al., 2013; Roehrig et al., 2011) and with indigenous leaders (Fickel, 2005; Grimberg & Gummer, 2013).

Centering Culture in Lesson Planning. Studies that provided teachers with a framework to develop culturally responsive practices and the support to work on their ideas

about the importance of equity practice in the classroom suggest that professional development can impact teacher's attention to how cultural connections can enhance learning of content. Using a lesson study approach with high school life science teachers, Brown and Crippen (2016) found that when teachers engaged in critical reflection about their practices, while also learning about the experiences and needs of their students, they recognized culturally responsive strategies and identified culturally relevant science topics. Teachers worked in collaborative groups tasked with identifying student learning goals and co-planning lessons designed to be responsive, reform-based, and reflective of identified goals. Each teacher taught the collaboratively designed lesson while colleagues observed and collected data about their practices and their students' actions. Teachers used practices that repositioned students as leaders in the learning process and employed strategies to promote interaction and discourse. They attempted to make their instruction connect to students' cultural backgrounds and were successful in some cases. However, teachers struggled to integrate core science ideas with culture. Brown and Crippen (2016) cite the most significant barrier to integrating culture into curricular planning as the teachers' limited knowledge of students' cultures. The authors found that providing teachers with a template that guided them in making connections between students' culture and the content was helpful and suggest providing resources and time for teachers to learn about students' home, community, family traditions, and out-of-school experiences. Their finding is consistent with Ladson-Billings (1995) suggestion that teachers need to develop their own conceptions of culture and equity before they can value the diverse experiences of their students.

Johnson (2011) used a transformative professional development framework in their work with two middle school teachers of Hispanic students. This three-year study suggested that

teachers can shift perceptions of self and others so that they are more supportive of diverse students. In the second year of a three-year program, teachers focused on developing new lessons that "incorporated inquiry, scaffolding instruction, cooperative learning, teacher empowerment, classroom management, and cultural aspects of the Hispanic students lives into the teaching of science" (p. 176). Teachers successfully made connections to cultural foods, careers, and everyday lives of their students. Data analysis indicated that teachers became aware of inherent challenges that diverse students face that are out of their control and recognized that "opportunities to learn for diverse students are sometimes inequitable" (p. 194). As a result of the professional development teachers saw themselves as providers of opportunity and hope. They demonstrated empathy and the ability to provide a comfortable space for learning. Johnson (2011) concludes that both teachers in the study realized the rewards of attending to culture as a "sociopolitical approach" when they experienced their students "utilizing creativity and critical thinking to think like a scientist and navigate social inequalities that they would encounter now and throughout their lives" (p. 194). Centering culture in the design and implementation of science lessons can give value to student's ways of knowing and reposition the cultural experiences of students outside the classroom as entry points for learning. This study is designed to provide participants with the opportunity to consider connections to student's everyday lives and culture as equity practice, addressing the need for in-service teachers to engage in teaching that centers students' ideas.

Indigenous Knowledge. Learning about culture requires time, introspection, and opportunities to engage with diverse people and diverse perspectives. When teachers learn with native communities they can successfully learn to integrate cultural referents with science content (Fickel, 2005; Grimberg & Gummer, 2013; Y. Nam et al., 2013; Roehrig et al., 2011).

Fickel (2005) describes professional development designed to support teachers collaboration with Native Alaskan Elders to determine teacher learning opportunities that successfully increased understanding of history and culture. Grimberg and Gummer (2013) found that collaboration between tribal advisors, faculty members, and teachers had positive impact on teacher's knowledge of tribal cultural and meaningful connections to science content. In this study, participants gathered in day-long monthly meetings, a two-week summer institute, and a three-day summer cultural camp designed to "develop teachers' knowledge of the tribal cultures; model teaching methods and science content applications congruent with the cultural practices of the tribal communities; enhance teachers' science knowledge; and enhance teachers' knowledge of how to teach science" (p. 18). Science and education faculty worked closely with tribal advisory teams to identify intersection points between American Indian culture, school science, and science teaching. Science content focused on Earth Science, Astronomy and Weather and Climate, and Physics aligned with the local Montana State Science Standards. For example, when teaching accelerated motion, teachers identified cultural practices of arrow making and throwing, and the game of basketball. Authors concluded that the designed unit reflected a "culturally responsive approach because the culture of the tribes was integrated in an authentic way: on-site, relevant to the students' and teachers' life experiences, and presented by community members who held mastery of the cultural practices" (p.19). They conclude that increases in student's science content knowledge resulted from teacher's thoughtful recognition and implementation of practices that leveraged the intersection between tribal, science teaching, and school science cultures.

Also working with teachers of students in American Indian communities, Y. Nam et al. (2013) and Roehrig et al. (2011) recognize that teachers come to science teaching with various

levels of understanding about culture and that some are more likely to embrace the importance of culture than others. Y. Nam et al. (2013) describe teachers in three broad categories regarding culturally responsive teaching:

> 1) Those who could give clear examples of and use culturally relevant science teaching in their teaching, 2) Those who expressed the need to use culturally relevant science teaching but lacked the knowledge of how to implement, and 3) Those who did not articulate a need for culturally relevant science teaching, seeing their American Indian students as the same as any other student (p. 163).

The study included 38 teachers participating in two three-year teacher professional development programs designed to support climate change education in American Indian communities. Y. Nam et al. (2013) found that even when teachers expressed a deep understanding of culture and the importance of leveraging culture in teaching science, they had to negotiate what they were required to teach with what they wished to teach. There are systemic barriers to teaching with attention to culture embedded within the institution of education. One teacher from an entirely Native America school expressed the dilemma, stating,

> Unfortunately, with our standards, we are being, our hands are being more and more tied. We have to stick to what we are supposed to do with the standards. But the standards are based on the western point of view on science (Y. Nam et al., 2013, p. 160).

Working with elementary teachers for two years, Roehrig et al. (2011) found that "sustained, culturally-based science professional development can positively change the quality of science teaching" and that teachers in the study "engaged the children in culturally-relevant and investigative science and mathematics activities." Researchers observed that ‘‘look more, listen

more and notice more" (p. 576) as a result of the culturally-based science professional development.

Chinn (2007) worked with 19 science and mathematics from eight different countries during a ten-day professional development institute in Hawaii. The researcher connected science learning through a place-based approach centering indigenous Hawaiian experience and connections to the natural world. Teachers engaged in math and science activities including collaborative action research leading to recognition of the sociocultural and ethical contexts of education. Through the use of decolonizing methodologies intentionally designed to orient content around sustainability and environmental literacy, Chinn (2007) supported teachers shift in thinking about learning science and math from a place-based, culturally grounded perspective.

Bancroft and Nyirenda (2020) conducted a review of literature on K-12 equity focused science teacher professional development. They reviewed 36 studies, coding for professional development context, research design and methods, and main findings of the studies. They determined that all 36 studies included programs that focused on science content and 32 of the 36 studies focused on both content and equity practices. Professional development providers, individuals other than the classroom teachers, were responsible for development of the lesson content in most studies. Researchers contend that this model of external development and expected teacher implementation of curriculum contributes to teacher's reluctance to enact curriculum and inability to attend to students experiences in the lessons (Cunningham & Carlsen, 2014b). Thirteen of the 36 studies reviewed by Bancroft and Nyirenda (2020) include models where teachers co-constructed lessons with developers. As Y. Nam et al. (2013) described, when curriculum is written by individuals who lack knowledge or appreciation of community culture, lesson implementation can feel disconnected from student lives. However, when curriculum is

co-constructed to center local knowledge and value students experience, teachers and students can be more immersed in the learning process (Cunningham & Carlsen, 2014b; Grimberg & Gummer, 2013; Johnson, 2011).

Few studies included indigenous perspectives and direct connections to local culture in the curriculum writing process. They stood out as exemplars for valuing the science-related assets of communities when creating learning opportunities. Each example included intentional equity focused professional learning which required time, support, and respectful collaboration. Centering student culture is not commonplace practice in schools and too often curricula written by external developers are disconnected from students lived experiences. The studies reviewed here demonstrate the meaningful connections that can be made when students' culture is central to learning. The work done in this study addresses the need to understand how teachers learn to center students' ideas as equity practice.

Classrooms as Sites for Learning. Action research positions the teacher as the investigator, using the classroom as a site for learning and inquiry about teaching (Cochran-Smith & Lytle, 1999). Like lesson study, action research provides a framework for teachers to systematically analyze their own practice. Brenner et al. (2016) conducted a study of study of 12 teachers engaged in a two-and-a-half-year professional development program, *Teaching for Equity in Mathematics and Science Education* designed and implemented by the researchers. Using a community of practice framework, researchers designed the professional development to place issues of equity and diversity front and center. Each teacher identified initial "wonderings" and developed a research question that had a specific connection to equity in their teaching. They collected and analyzed data from their own classroom as an action research project. Members of the group shared their research questions with others for feedback and discussion. Researchers

collected data from teachers' research projects, classroom data such as student surveys, interviews, and video of classroom instruction. They reviewed all professional development seminars and meetings. Most teachers connected their research questions to issues of equity either initially or because of collaborative discussions with others. All but one teacher developed a deeper sense of their role as agents of change in both the classroom and the larger school community. Analysis revealed that participants view of families and communities did not change significantly. Some participants recognized that parents valued education while others maintained a deficit view of parents' ability to support their student's success in school. Overall, the authors concluded that the teacher research model is a useful professional development strategy to support deeper understanding and attention to issues of equity and diversity in classrooms.

Learning to notice the specific decisions and moves that teacher's make with respect to integrating culture into teaching can be supported through the use of direct observation. In a multiple case study analysis of six elementary science teachers of English Language Learners, Minchew Deaton et al. (2014) used a web-based video analysis tool to allow teachers to view their own science teaching and engage in reflective writing about their teaching and their students connection to content. Researchers noticed "participants used their reflective writings to focus on their awareness of their students' language and culture instead of solely focusing on science content and pedagogy" (p.212). Through the intervention teachers demonstrated evidence of leveraging cultural funds of knowledge to make students feel valued and to create meaningful and culturally relevant connections to the content. Minchew Deaton et al. (2014) recognized the need for teachers to deepen their understanding their students' cultures and family backgrounds and continually reflect on cultural connections to content.

Rosebery et al. (2016), used video to support teacher's collaborative noticing of student sensemaking and the use of discourse strategies to support student's construction of meaning when learning science content. Twenty-eight early career teachers used a guided protocol to interpret teacher actions and responses to student ideas. The study participants learned to see students use of language, gestures, and visual representations as positive assets and paid closer attention to students' diverse sense-making repertoires as intellectually generative.

Focusing on Language-Culture Connection. Hudley and Mallinson (2017) designed and implemented a professional development with the goal of providing teachers information and space to dialogue about language, literacy, and culture in STEM education settings. Sixty teachers participated in workshops focused on the following topics:

> 1) Conflict between school and student culture, 2) Biases against non-standard varieties (dialects) of English and students who speak them, 3) Linguistic/cultural mismatches and student achievement, 4) Confronting standard-English texts, 5) Structural linguistic issues, 6) Building linguistic and cultural competence (p.644).

Using data from a presurvey, the researchers developed professional development sessions that were responsive to teachers shared knowledge of language, literacy, and culture in their teaching. Teachers volunteered to participate and already held the position that language, literacy, and culture mattered in teaching. Through the workshop they were able to think critically about their own use of language in science and the value they placed on student's ability to express what they know. For example, teachers discussed how to address the use of standard English and how to select examples in their teaching that did not create barriers for students. They interrogated experiences they had as teachers with their colleagues and decisions they had made in their own

practices with the intention of being more culturally and linguistically aware. As a group they discussed strategies and tools for working directly with students.

Leveraging Hudley and Mallinson (2017), Lodge (2017) explains the value of Jamaican Creole in the teaching of science to Jamaican students who speak the language. The author describes the significant stigma against Jamaican Creole in education and situates this in context of highly underachieving population of Jamaican students in science. Drawing on their own experience as a science teacher in Jamaica, Lodge (2017) describes how the use of Jamaican Creole can be an entry point for students if valued as such. They state,

> The Creole-speaking child will follow the teacher only so far as their language practices remain in common; they will seek to interpret what is alien to their thinking in terms of their own language and will either disregard in entirety what does not fit their own usage or misinterpret what appears to resemble their own practices (p. 672).

As G. Gay (2010) contends, "Students of colour come to school having already mastered many cultural skills and ways of knowing. To the extent that teaching builds on these capabilities, academic success will result" (p.213). This body of literature suggests that language is an important aspect of culture and has a significant influence on student's ability to learn. Language and culture are an integral aspect of teaching and learning and are a component of equity-focused pedagogy that is explored with participants in this study.

Culture is not a Fixed Condition. The professional development models reviewed here describe specific groups of teachers, often working with teacher educators and researchers, thinking about culture and cultural connections to content and learning how diverse student experiences outside the classroom can be valued for deeper learning inside the classroom. Culture is considered in a variety of ways and integrated into teaching through different

approaches such as lesson planning with cultural connections, inclusion of Indigenous knowledge, and using various tools to support teachers with taking a critical lens on their own teaching. The majority of studies reviewed position culture as something that students have, or possess, as a fixed condition (Carlone & Johnson, 2012) that can be used as a reference point for making connections to content. Others support teachers learning to recognize practices that position students and families as assets (Alvaré, 2017) .

Carlone and Johnson (2012) caution that too often, "science educators 'may not understand the nuances or historical roots of the concepts of culture they take up in their work" (p. 151). Alvaré (2017) shares work with elementary teachers located in the United States and Trinidad and Tobago, engaged in professional development focused on inquiry-based teaching of environmental education. Despite a well-intentioned, theoretically driven program designed to support elementary teachers culturally responsive practices, the work resulted in 'othering' of some groups rather than the intended co-construction of culturally relevant pedagogy. Alvaré (2017) reports that the implementation of the professional development mistakenly relied on "third-party 'experts' when attempting to craft a culturally responsive pedagogy." Reflecting on errors in the design of the experience, Alvaré (2017) suggests "we should have consulted directly with the 'students' themselves" rather than asking individuals not directly connected to the culture. If the researchers had given students a more significant voice in the program design prior to the implementation, they "would have given students a sense of empowerment and ownership of the process" (p.47). Alvaré (2017) cautionary work suggests that facilitators and researchers carefully consider the way in which culture is represented in professional development.

The literature reviewed provides a foundation for this study which uses a design-based model to provide teachers a structured opportunity to make sense of their own ideas about equity

in their teaching. Many of the tensions revealed in the literature are supported in this study and will be discussed in subsequent chapters. In the next section, I describe the methodology including context, participants, and my positionality as both the researcher and member of the collaborative community of practice.

Chapter Three: Methodology

The strength of qualitative research is in the process of understanding the relationships and experiences that people have regarding a specific issue. With respect to understanding how teachers think about and engage in equity-focused practices, qualitative methodology was ideal for learning how participants interpreted their experiences and made sense of their work. In this study, qualitative methodology provided a systematic process for realizing the meaning of decisions, experiences, and actions, and for understanding the social construction of teacher learning with a practice focus.

To establish the background for the work, I describe the unique features of the professional learning experience that participants engaged in prior to this inquiry. Then I justify selecting a convenience sample and describe the process of inviting participants. After introducing each of the ten participants, I discuss my positionality as the researcher and facilitator of the community of practice by positioning my work within the "three-story challenge" of professional learning (Windschitl & Stroupe, 2017). Lastly, I discuss how the approach of design-based research was critical for defining the strategies and implementation of the professional learning model from which I addressed three research questions through the lens of sensemaking:

1. How do teachers make sense of equity through negotiations with peers in a professional community of practice?
2. How do participants translate their ideas about equity in planning for enactment?
3. To what extent are "science and engineering practices" and "equity" related components of teachers' practice?

Study Context and Participant Selection

Participants were graduates of a professional learning program, GenerationSTEM,[2] which served K-12 teachers seeking to enhance their professional knowledge of integrated STEM content and practices. The program emphasized integration of NGSS three-dimensional teaching and provided opportunities for teachers to engage with scientists and engineers in online, interactive webinars. Eligibility requirements included certification as a PK-12 educator and an earned bachelor's degree. All educators in the GenerationSTEM program took at least three graduate level courses and completed a capstone project focused on sharing STEM teaching practices and content with others in their local context. All GenerationSTEM participants completed a common course in foundations of STEM teaching. The second and third courses were selected by the participant from available options each semester. During their final semester, they designed and implemented a capstone project to share what they learned with colleagues in each of their individual teaching contexts. The goal of the capstone project was to share meaningful aspects of the program with others and to support classroom teachers' leadership and agency. Participants autonomously selected aspects of the GenerationSTEM program that they identified to be meaningful in their teaching context and decided how they wished to share what they had learned with others.

A subset of educators who enrolled in GenerationSTEM did so with support from a biomedical research company interested in supporting STEM teachers locally. They were selected for the BioSTEM[3] experience prior to beginning the coursework and committed to completing both the GenerationSTEM program and the subsequent BioSTEM laboratory

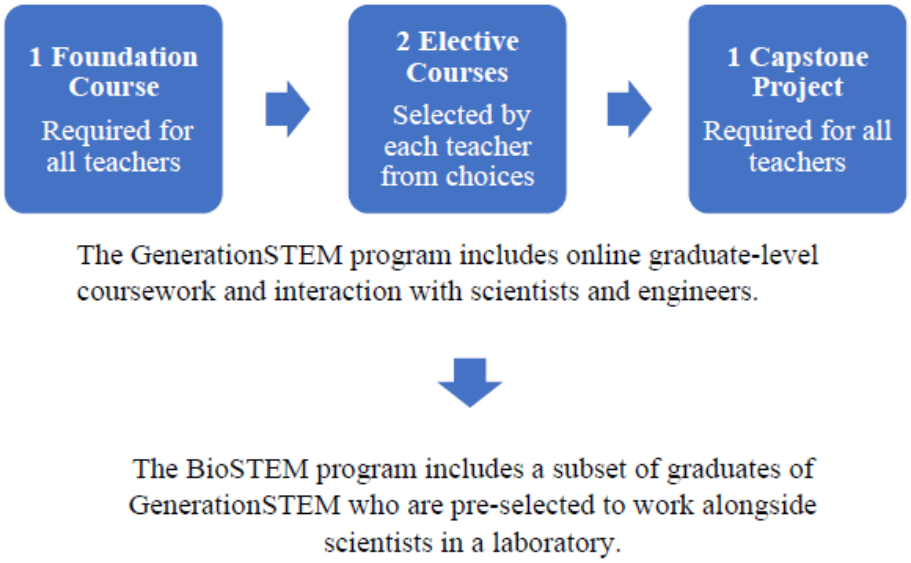
[2] GenerationSTEM is a pseudonym.
[3] BioSTEM is a pseudonym.

experience. GenerationSTEM reported 935 graduates in 15 years. Sixty of these participants also completed the BioSTEM laboratory experience.

The original conception of this study included an in-person intervention followed by classroom observations with the cohort of educators completing BioSTEM in Summer of 2020. However, in the time between proposal and implementation, the study shifted in response to the unprecedented global pandemic caused by the virus SARS-CoV-2. Safety concerns removed any opportunity for direct classroom observations and privacy regulations limited teachers' ability to share video recordings of their teaching. In response to these constraints, I shifted my attention to supporting teachers in a collaborative community of practice focused on the integration of equity practices in teaching of the SEPs. Following the onset of the global pandemic, and pursuant to the logistical constraints that were imposed as a consequence, I made an intentional decision to continue professional learning activities with recent graduates of the GenerationSTEM and BioSTEM programs. All ten of the participants were graduates of GenerationSTEM, during which they each participated in graduate level courses and a non-credit capstone project. Four participants were also part of the BioSTEM program, and all participants graduated within five years of the beginning of the study.

Figure 2

Overview of the GenerationSTEM and BioSTEM Programs

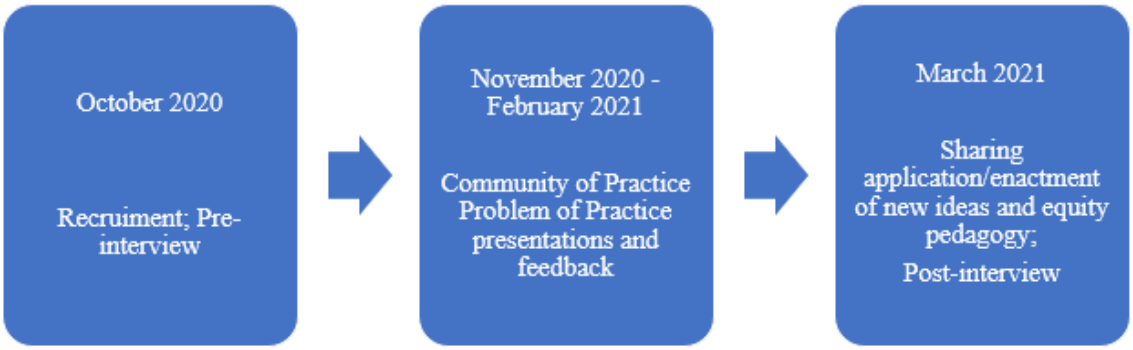


On October 2, 2020, I sent an email invitation to 67 graduates informing them of the opportunity to participate in a community of practice focused on equity and the SEPs in their teaching. Employing criterion-based selection, I selected the invitees from a database of teachers who had graduated within the past five years from the GenerationSTEM and BioSTEM programs. I limited participants to those teaching in two neighboring states in the Northeast United States, both which followed state adopted standards based on the NGSS. I also chose to limit the size of the target population pool because I sought to work with approximately ten participants and based on my knowledge of the target population, I was concerned about too large a participant group. Within five days of sending the initial email, 12 teachers responded with interest. Two of the teachers emailed again, prior to initial interviews to rescind their interest, citing that they already had too many existing teaching responsibilities. Both teachers

said they would like to be involved later, if possible. The remaining ten teachers voluntarily participated in an online community of practice that met ten times over a 16-week period (Figure 3).

Figure 3

Community of Practice Timeline



The ten teachers represent a purposeful, convenience sample selected because of their willingness to take part in the study. Purposeful samples are most appropriate when the researcher "wants to discover, understand, gain insight and therefore must select a sample from which the most can be learned" (Merriam & Tisdell, 2016, p. 96). Using purposeful sampling allowed me to gain an in-depth understanding of the specific cases, referred to as "information-rich cases" (Merriam & Tisdell, 2016, p. 96).

Participants

Participants included teachers with a varying number of years in the profession (least = three years; most = 23 years), working across all grade levels (K-12) and with students in a range of demographic categories (Table 1). Below I describe each participant individually, including their teaching context, the number of years in the profession, and their content area(s). I include a brief description of each participant based on their personal descriptions in the pre-interview.

During the time period of this study schools shifted to hybrid and remote teaching schedules. Hybrid schedules included teachers facilitating classes with some students at home logging into virtual classroom software to listen to and interact with teachers while also teaching students in the classroom. Fully remote teaching days included all students learning outside the school with some level of interaction with teachers and classmates using technology. The schedule varied across districts and depended on safety concerns due to spread of COVID-19. All names used throughout the study are pseudonyms.

Carisa

Carisa taught middle school general science for 18 years and was in an urban public school during the study period. She was dedicated to educating students to understanding the purpose behind their learning and is passionate about students making connections to content rather than memorizing everything in the book. Carisa sought out opportunities to improve her teaching, recognizing that "the more I learn the better I can serve my kids." Carisa taught students in a hybrid model during the study period.

Eddie

Eddie taught seventh grade science in an urban charter school. He was in his third-year teaching overall and was teaching at a new school during his third year. He taught general science during the study period using a hybrid model. Eddie loved exploring with his students, supporting engagement with phenomena and letting students "get their hands dirty."

Alana

Alana taught sixth and seventh grade students in an urban public school district. During the study period, she taught social studies and science in a hybrid setting. She was a certified science teacher, licensed in grades seven through twelve and did not have a background or

certification in social studies. Alana was in her tenth-year teaching in the United States and had previous experience as a teacher in India, where she was educated.

Tom

Tom was a high school teacher in a suburban public school district. He was in his 12th year of teaching, five of those years in his current position. Tom taught forensic science and biology. Tom recognized that he "knows how to teach well, but there is no one right way to teach" and entered the community passionately seeking knowledge from other people who "are better than me at teaching and will make me a better teacher." Tom taught with a hybrid model during the study period.

Penelope

Penelope was a high school biology teacher at a private Christian school attended by students from a wide geographic area. She had been teaching in the United States for 15 years. Penelope taught using a hybrid model during the study period. Her original teacher certification and first years in the classroom were spent in classrooms in the Netherlands. Penelope described teaching as a learning journey that she and her students embarked on together, where she was the lead explorer on a journey of increased understanding.

David

David taught eighth grade general science in a suburban public school. He taught in a completely remote setting during the study. David was motivated by seeing students learn, going from not knowing how to do something to enjoying it. He described himself as a hands-on teacher who was encouraged by student feedback. He enjoyed learning from other educators, seeing what they do and putting his own spin on the implementation.

Bryce

Bryce taught math and science to students in grades 10-12 in an urban public school district. Bryce was a self-described "sponge of teaching techniques" who strove to make connections between real-life experiences and the content he taught. He worked in the community where he was raised. Bryce was teaching hybrid during the study period.

Jodie

Jodie taught in a suburban public district and had been teaching fourth grade for 15 of her 16 years in education. She valued cross curricular teaching and strove to integrate her own education in writing instruction when teaching STEM. She was a contributing developer of the science curriculum currently being implemented in her suburban school. During the study period she taught students who were remote and also in person, and some days she taught students in a completely remote setting.

Kathryn

Kathryn was the dedicated kindergarten through fifth grade STEM teacher in a suburban public school district. She described herself as a bridge between STEM experiences and her students and maintained the goal of exposing students to what it was like to be a scientist or engineer. Kathryn was teaching hybrid during the study period.

Lucy

Lucy was the kindergarten through third grade STEM teacher and the media specialist charged with creating and implementing a STEM program in two schools within one suburban public district. She was in her 23rd year of teaching and was a lifelong resident of the same community. Lucy described herself as respectful of her students and eager to create a respectful

student-focused learning environment. Lucy was in a hybrid teaching scenario during the study period.

Table 1

Participants

Participant	Race/Ethnicity, Gender Pronouns	Grade level and subject area taught	District Demographics	Student to teacher ratio
Tom	White, he/him	High School, Forensic Science and Biology	43% Hispanic 32% Caucasian 16% Asian/Pacific Islander 9% Black	14:1
Bella	Hispanic, She/her	Middle School, General Science	65% Hispanic 28% Black 5% White 1% Asian	14:1
Lucy	White, she/her	Elementary STEM	93% White 3% Hispanic 1% Black 1% Asian	12:1
Penelope	White, she/her	High School, Chemistry	59% White 19% Asian 11% Black 8% Hispanic 3% Multiracial	11:1
David	Black, he/him	Middle School, General Science	46.4% Black 25.9% White 19.1% Hispanic 4.8 % Asian	11:1
Eddie	Hispanic, he/ him	Middle School, General Science	76% Hispanic 22% Black 1% Asian	18:1
Jodie	White, she/her	Elementary science	62% White 26% Hispanic 7% Black 2% Asian	11:1
Kathryn	White, she/her	Elementary STEM	50% White 34% Black 9% Hispanic 3% Asian 1% Other	11:1
Alana	Indian (from India), she/her	Middle School, General Science	40.6% Hispanic 25.5% Black	22:1

		and Social Studies	16.2% Asian 15.1% White	
Bryce	Puerto Rican, Italian, Bryce	High School, Chemistry	40.6% Hispanic 25.5% Black 16.2% Asian 15.1% White	22:1

Researcher Positionality

As a qualitative researcher, I recognize the importance of my positionality and framing of my research for participants and for the overall contribution to the field. I am constantly learning, reframing, questioning, and attempting to notice the "seen, unseen, and unforeseen" in my research (Milner Iv, 2007). As a teacher educator seeking to understand the sensemaking processes of teachers, I attempted to position myself as a co-learner and facilitator. That said, I recognized the hierarchical structures of the field and was keen to how existing perceptions may have influenced my positionality in this study. Windschitl and Stroupe's (2017) architectural metaphor of teacher education as a "three-story challenge" is a helpful tool for considering my positionality. While the authors apply the metaphor within the context of preparing novice teachers, I believe the model is applicable to in-service professional learning, as described in this study. The three-story metaphor articulates the interconnected system of student, teacher, and teacher educator learning required to uphold the responsibilities of each. For example, for students to realize the goals of understanding the natural world and participate in science practice and discourse, they need opportunities that support knowledge development that are designed and enacted by teachers. Teachers require knowledge of how to create opportunities for students to participate in science. They must be knowledgeable of the goals for students, described in NGSS and related documents. Likewise, teacher educators must understand the how teachers

engage with students in the classroom in order to model teaching that will support their improvement as teachers.

Given the practice focus of this work, it was essential that I have a sound understanding of what students are responsible for and what teachers are responsible for as I created a model for teachers to learn collaboratively. The model was founded on the four design principles described in Chapter One. Windschitl and Stroupe (2017) refer to knowledge of what teachers are responsible for, and knowledge of what students should know and be able to do, as the requisite understanding for teacher educators. In my position, I used my professional knowledge to design a model in support of teacher learning, in essence working in the "in between" space where all levels of learning−student, teacher, and teacher educator–needed to be considered. The outcomes of this study are the result of group members, both the in-service teachers and me, as the researcher, upholding responsibilities as part of the interconnected system in which learning took place. I was able to make sense of each participant's sensemaking because individuals committed to the work and upheld their responsibility to others.

Due to my relationship with teachers in the GenerationSTEM and BioSTEM programs prior to beginning this work, I was able to expand upon an existing interconnected system of teacher learning. I invited graduates of the GenerationSTEM program because they shared a common experience of thinking about STEM teaching within their unique contexts and because I had an existing relationship with each of them as the director of the GenerationSTEM program.

In this role, I was responsible for enacting the mission of the program and partnering organizations−to build capacity with K-12 teachers to enact integrated STEM teaching practices. At the time of the study, I was responsible for overseeing the instructors for each STEM education course that teachers in the program took. I was never the instructor for any of the

participants' coursework and was not involved in assessment of coursework. I did oversee doctoral level instructors of record who were responsible for all assignment grading and feedback. I served in a collaborative and supportive capacity when the participants were engaged in the program and remained in contact with all graduates to share opportunities to attend guest speaker events with experts in specific STEM fields, and support teachers with resources as needed.

From an epistemological perspective, the position that I held allowed for relationship-building with study participants so that I minimized the distance between myself and those from whom I sought to gain understanding. I contend that the study design afforded me the important opportunity to build on professional relationships and conduct a close investigation of a collaborative group of individuals to gain an understanding of perspectives and meaning making regarding equity-focused practices (Creswell & Poth, 2018). In the following section, I describe how my position as teacher educator afforded me the ability to integrate a design-based research approach and analyze data to understand teacher learning.

Applying Knowledge of Teaching to Professional Learning

The two primary goals of this study were to provide teachers with a collaborative space to explore issues of equity in their specific teaching environments and to research teacher learning in an online collaborative community of practice. Addressing the first goal, I employed a design-based research approach to create and implement a professional learning model focused on improving teacher understanding. As discussed in Chapter Two, the design of this study is situated in current literature on professional learning. I employed qualitative methodology to respond to research questions and contribute to knowledge in the field of science education. Fishman et al. (2013) suggest that design-based research focuses on the following principles:

> 1) a focus on persistent problems of practice from multiple stakeholders' perspectives; 2) a commitment to iterative, collaborative design; 3) a concern with developing theory and knowledge related to both classroom learning and implementation through systematic inquiry; and 4) a concern with developing capacity for sustaining change in system (p. 142).

In the following section I outline the first goal, the design of a professional learning experience based on the values of design-based research methodology.

Persistent Problems of Practice from Multiple Stakeholders' Perspectives

Leveraging design principles described in Chapter One, I intentionally invited participants to collaboratively make decisions about how the online meeting time was used. Through my experience as a classroom educator, and as teacher educator for several years, I recognized the importance of supporting teachers with what they wished to focus on as professionals with practical knowledge of their students and contexts. This approach is notably different from common professional learning experiences for teachers (Banilower et al., 2018; Darling-Hammond et al., 2017; Darling-Hammond et al., 2019). Teachers face many conflicting demands and their beliefs, experiences, and professional identities are important factors influencing their ability to take up change (Hawley & Valli, 1999; Penuel et al., 2007). Positioning myself as a facilitator of the group, I offered guidelines to structure the discussion and focus the work on attention to equity in science teaching. I purposefully involved the group in making decisions about logistics–when and how the group spent time together and what was discussed. Collectively, participants and I agreed to use a tuning protocol, which I adapted from McDonald et al. (2015) and Settlage and Johnston (2014) and called *Teaching with Attention to Equity.* The protocol guided each participant in selecting a persistent problem of practice to share

with the group for discussion and feedback and structured group routines around turns of talk−routines recognized to be useful in providing opportunities to learn (Horn & Little, 2010). Horn and Little (2010) suggest that there is substantial agreement in the field of education that using "conversational routines" and "turns of talk" can establish collegial relationships that can lead to productive efforts for improvement (p.184). Cheung et al. (2018) suggests that when classrooms teachers have support to take on leadership roles and address problems of practice that they deem important, a culture of collaboration can lead to improvement.

Commitment to Iterative, Collaborative Design

The structure of the group was iterative, and participants made minor adjustments to the tuning protocol in the moment, as needed. The community aspect of the group was important for engaging in the generative work of thinking about and enacting teaching practices. To ensure that the design of tuning protocol worked well for all members of the group, I included opportunities for feedback and made decisions about meeting times and dates collaboratively. Throughout the study, I made time for group check-ins and was responsive to individuals' needs to manage the commitment with their other responsibilities. For example, the group decided not to meet during school vacation times and collectively decided that we needed two additional meetings after all participants had presented their problems of practice. I intentionally modeled collaborative learning strategies that could be adapted to classroom settings.

As a community of practice, the group shared a collective passion for their teaching practice and dedicated themselves to learning how to do it better through regular interactions with one another. Following Wenger's (2010) structure for communities of practice, this community included four components. The first component was the *domain*; the shared interest in developing understanding of equity-focused teaching in science classrooms focused on the

SEPs. All members of the community brought knowledge of STEM integration, resources they were willing to share, and a dedication to improving their practice. The second component, *community,* was defined as the one-hour, online meetings where members engaged in sharing and feedback structured around the tuning protocol. Finally, the *practice* was manifest in the outcomes of the community efforts−the discussion, feedback, shared resources, and adjustments to planning.

Developing Theory and Knowledge

The group set out from the beginning to address issues of equity in their classrooms, a topic that they felt aligned to their needs and interests as teachers. Each teacher recognized the alignment between the stated goals of the community and either their personal goals or those of their school setting (Penuel et al., 2007). I intentionally focused the group on the active work of sensemaking and thinking about equity practices that could be implemented in the classroom across contexts, a decision informed by empirical evidence that teachers' practice is an essential component of student learning (Ball & Forzani, 2009). Recognizing that sensemaking is an ongoing process, I focused on the short-term outcome of applying knowledge to practice and engaging in ongoing reflection about the decisions that worked and the decisions that required continued work. While I approached this work with my own ideas about equity pedagogy in science teaching, I did not impose my own definitions of equity on the group. Rather I participated in the discussion by presenting the approach to equity that I identified most strongly with from the literature and from my own experience. I listened to participants ideas about equity and facilitated discussion with the group so that each participant could reflect on their ideas more deeply. My intention was to meet each participant where they were in their thinking about equity and allow them to deepen their understanding through collaborative discourse.

Developing Capacity for Sustaining Change in Systems

While not measured as part of this 16-week study, the design of the professional learning model responds to the recognized need for teachers to engage in generative work of making sense of equity across contexts (Thompson et al., 2019). Discussions focused on how to enact equity practices and how to engage other like-minded colleagues in each teachers' context. At the time of this study, many school districts were implementing equity committees in response to national conversations about systemic racism. Community of practice discussions and post-interviews included dialogue about how participants were thinking about their roles and next steps in their individual school contexts. The context for this work was important. Using design-based research as a framework, I was able to learn both about the model for professional learning and gain an understanding of the individual learning that took place during the study period. It also allowed for iterative design and adjustment in response to individual and group needs.

Data Sources

Each data source was directly aligned to one of the three major research questions that I set out to respond to in this inquiry (Table 2). Data collection began in November 2020 with pre-interviews. Upon volunteering to participate in the study and signing the Institutional Review Board approved consent form, each teacher signed up for an interview time slot using the online tool, Calendly. All interviews were conducted via Zoom, recorded, and transcribed.

Pre-Interview

Guided by an interview protocol (Appendix A), I utilized a semi structured approach to allow the participants to speak comfortably and openly (Merriam & Tisdell, 2016) and share how they grappled with and made sense of equity in their teaching and the SEPs. Given the generative nature of this work, I intended to understand where each participant was regarding their thinking

about equity prior to engaging in the community of practice (Ball, 2012). Participants shared their approach to teaching and their ideas about equity in the classroom. They described their classroom environment. I asked them to explain the SEPs and to talk specifically about the importance of students' culture. I provided interview questions in advance and used them to guide the conversation, sometimes straying from the order of questions as listed to allow conversation to flow naturally.

Table 2

Research Questions and Data Sources

Research Question	Data Source
How do teachers make sense of equity through negotiations with peers in a professional community of practice?	Tuning Protocol Presentation, Pre-interview transcripts Survey Post-interview transcripts
To what extent are "science and engineering practices" and "equity" related components of teachers' practice?	Tuning Protocol Presentation Post-interview transcripts
How do participants translate their ideas about equity in planning for enactment?	Tuning Protocol Presentation, Post-interview transcripts Specific examples of planning and enactment of practices Survey

Note: The research questions are the basis of the data collection and analysis.

Tuning Protocol Presentations and Discussions

Participants used a tuning protocol to structure their presentations (Appendix B). Each participant selected a problem of practice or lesson that they wished to improve upon through an equity lens. The selected topic was detailed enough to elicit a good discussion. Participants were asked to include the following items in their ten-minute presentation: a statement of the problem, a statement explaining what they wanted the group to focus their feedback on, the connection to

equity, and the connection to the SEPs. Participants were free to present the problem of practice in any way they wished given those guidelines. After the ten-minute presentation, during which the presenter spoke without interruption, the respondent's, made up of the other nine members of the community, were given five minutes to ask clarifying questions. These questions were limited to matters of fact, as opposed to judgements or feedback.

The following ten minutes was dedicated to warm and cool feedback. During this time, the presenter was silent and listened to group discussion. I provided constructive prompts to support the group in offering constructive ideas and reminded them that the goal was to advance the presenter's thinking about their teaching with attention to equity. The final five minutes of each presenter's time was dedicated to reaction to the feedback. During this time, the presenter could respond to any aspect of the discussion as they wished.

Survey

At the end of community of practice session nine, after all participants had an opportunity to present their problem of practice and receive feedback, I asked participants to complete a survey (Appendix C). The survey was intended to allow participants to share their experience in the community of practice and describe their ideas about the core components of the work– equity, science and engineering practices, and engaging in a collaborative community of practice. The survey provided a tool for "uncovering the meaning they attribute(d) to their experiences" (Merriam & Tisdell, 2016, p. 6). I asked participants to explain equity, describe the importance of SEPs, make connections between SEPs and equity, and identify aspects of the discussions that occurred in the community of practice sessions that were most meaningful to them. I used these responses to focus the post-interview discussion for each participant.

Post-Interview

I met with each participant individually to clarify their responses to the survey questions and discuss their current ideas about equity as teachers of the science and engineering practices. I focused the conversation based on where each participant was in thinking about equity when they joined the community of practice, and where they were at the time of the post-interview. We also discussed any goals or plans they had for applying new ideas in their future work. I asked each participant to describe if and how they were thinking about teaching differently than when they joined the study. If they shared that their thinking had changed, I asked them to demonstrate how they had either planned for enacting changes to their teaching or had already enacted changes to their teaching.

Artifacts

During the post-interview, I asked participants to share how, if at all, they made shifts to their teaching. I requested examples of artifacts that demonstrated the changes. Some participants chose to discuss changes to lesson that they referred to in the pre-interview. However, most shared examples of changes made to lessons that they were currently work on. Given my goal of being responsive to participants needs and making the community of practice time helpful for what teachers felt they needed to work on to improve their teaching, I did not require that participants submit artifacts from a particular lesson. I reviewed the artifacts that participants shared and their explanation of how they made shifts based on the community of practice work. The process of listening to how participants either made changes or planned to make changes to a lesson based on their new understanding, provided an opportunity for me to understand how each participant translated new knowledge to their planning and enactment (Halverson, 2004).

Data Analysis

Data analysis is the systematic process of making meaning of data through "consolidating, reducing, and interpreting what people have said and what the research has seen and read" (Merriam & Tisdell, 2016, p. 202). Using an inductive qualitative approach, I systematically engaged in constant comparative method with the goal of making sense of the individual sensemaking processes of participants in the study as they interacted with one another through structured dialogue in a community of practice. The phenomenon of interest was teacher learning regarding equity-focused teaching of science and engineering practices and the participants' interactions were a key source of data for identifying how they each made sense of equity in their teaching. I read transcripts of interviews and community of practice presentations, watched recordings, and listened repeatedly to discussions to identify evidence of participants grappling with new ideas, planning to integrate those ideas into practice, and supporting one another in their sensemaking processes.

Making Sense of Equity

I sought to understand how teachers made sense of equity (research question one) and how they were able to identify opportunities to shift their practice with an equity lens (research question two). In essence, I attempted to make sense of their sensemaking processes. I inductively identified the occurrences when teachers grappled with new ideas and reasoned with how to address those ideas in their teaching. Odden and Russ (2019), in a review of the various theoretical constructs that employ sensemaking as a framework, determined that there are stages that are common to most sensemaking processes. The first step is the recognition that something is new; the stage I refer to as *noticing*. Noticing corresponds to Weick et al. (2005) acknowledgement that the individual who is making sense of something must be able to ask the

question "what is new?" Second, when trying to make sense of the new idea, individuals *apply knowledge* seeking explanations for why the new phenomenon exists. The "sense maker" tries to find ways to resolve the new idea within the context of their existing knowledge base. They then *reason* or connect ideas. They look for evidence that supports a shift in knowledge. The reasoning stage involves asking important questions, like "now what do I do?" and "how do I shift my thinking or my actions to incorporate this new knowledge?" The individual then *looks for inconsistencies* between the new knowledge and what they already know and decides how to proceed. Throughout this process the individual must resolve how the new idea confronts their practical knowledge (Allen & Penuel, 2015; Weick et al., 2005).

Using sensemaking as my framework, I addressed the first research question, *how do teachers make sense of equity through negotiations with peers in a professional community of practice?* by analyzing participants' problem of practice presentations. While there were similarities to participants' presentations, everyone selected a problem that they wished to discuss and that was unique to their context. Through dialogue with others, participants noticed inconsistencies between equity focused ideas and their teaching and reasoned with what to do with the new information. In some cases, participants were able to discuss the inconsistencies, while in other cases they shifted their teaching without articulating to the group why they did so. In Chapter Four, I present each participant's problem of practice and identify occurrences that led to individuals noticing and reasoning.

Addressing research question two, *how do participants translate their ideas about equity in planning for enactment?* I discussed evidence of how each participant enacted or planned to enact ideas following discussions. To make sense of participants' sensemaking processes about equity and teaching the SEPs, I coded pre- and post-interview data and problem of practice

presentations to identify inconsistencies between a teacher's identity and descriptions of their teaching. I repeatedly read and listened to transcripts of interviews and presentations. Upon identifying occurrences that led to new ideas, I reviewed findings with participants, a practice known as member checking. Member checking is considered critical for establishing credibility and to ensure that the data collected represents the views of the participant (Creswell & Poth, 2018).

Addressing research question three, *to what extent are "science and engineering practices" and "equity" related components of teachers' practice?* I share evidence of participants' planning and enactment with new ideas. Due to the nature of the study and the restrictions on visiting classrooms at the time the study was conducted, evidence of planning with new ideas and participants' shared examples of how they translated new ideas to their teaching served as evidence of the outcomes of their sensemaking process.

The unit of analysis for this study is the individual participant, working in their unique teaching context. However, as participants of the community of practice, they engaged with one another and pushed each other to think about equity when teaching the SEP. Through analysis of tuning protocol presentations and occurrences of noticing and reasoning, productive tensions emerged. Borrowing from Thompson et al. (2015) I used the term *productive tensions* to suggest the iterative nature of the work−the push and pull of dialogue and collaborative reflection involved in noticing and reasoning about new ideas to advance understanding and improve practice. This characterization also helped reveal ambiguities between teachers stated beliefs and their enactment of practices (Kennedy, 2016). I discuss productive tensions in the discussion of the findings in Chapter Five.

Making Sense of Teacher Agency

Analysis of the data through the lens of sensemaking revealed indicators of teacher agency. As participants shared the way that they progressed through their sensemaking process, I noticed contextual factors and aspects of their professional identity that either supported or presented challenges for enacting equity practices. As discussed in Chapter One, teachers can be agents for social justice teaching when they express certain perspectives. According to Pantić (2017) agency entails dedication to a purpose or a belief that a certain practice is worthwhile, referred to as sense of purpose. Teachers, when guided by their purpose, demonstrate their competency to achieve the desired outcomes. Competency is influenced by external factors such as resources and support in context. Pantić (2017) describes the scope of autonomy as the power that one has to make a difference and cites various factors that influence autonomy. These factors became important in the analysis of the data.

Analysis of pre-interview data, community of practice discussions, tuning protocol presentations and feedback, and post-interview data revealed markers of agency that emerged as important for making sense of participants' perceived ability to enact equity practices in their contexts. Using the constant comparative method, themes regarding teachers' sense of purpose for engaging in equity work emerged. I was able to identify occurrences where participants noticed their autonomy or lack of autonomy to enact equity practices in their unique teaching contexts. Context specific constraints on teacher autonomy emerged as an important outcome of the study. At times when participants noticed and grappled with ideas through conversation with others, they demonstrated the discourse rich tradition of sensemaking (Allen & Penuel, 2015). In the following two chapters, I apply qualitative methodology to share study findings and analyze

data sources to make sense of participants sensemaking process as they collaboratively engaged in thinking about equity pedagogy.

Chapter Four: Design of the Professional Development Model

My purpose in this chapter is to summarize the design and implementation of this design-based research study and the collaborative process of sensemaking that the ten participants and I engaged in during the 16-week study period. The specific structure of the community of practice space was consequential for participants' sensemaking. Therefore, I begin the chapter by describing the substance of the community of practice sessions, including the processes of setting up the community, creating norms, and deciding on a structure for collaborative dialogue. Participants began the work thinking about equity within their own contexts. Descriptions of five different ways that participants spoke of equity provides a starting point for understanding their beliefs about equity. I discuss participants sense of purpose for engaging in this work, an indicator of agency, and their willingness to grapple with new ideas, which is part of the generative work of sensemaking and improving practice.

The second part of this chapter includes a linear description of how each participant utilized the structured discussion time in the community of practice to work on a problem of practice that they identified as meaningful. I describe each problem of practice presentation, including occurrences in the dialogue that led to participants noticing new ideas and grappling with inconsistencies between their current thinking and the suggestions from other members of the group. For each participant, I discuss why incidences of noticing were consequential and represented moments when individuals began to organize new ideas and decide what to do next. I share the outcome of their sensemaking, bounded by the time period of this study, as examples of planning or enactment. As a result, the second part of the chapter reads in a linear way, as each participant's sensemaking process unfolds. In practice, however, the process of making sense of new ideas about equity was interconnected and reliant upon interactions with others. I

conclude the chapter by identifying the productive tensions that I noticed as the researcher and prepare to discuss the significance of these tensions for equity-focused teaching practices in Chapter Five.

Practice-focused Professional Learning in a Community of Practice

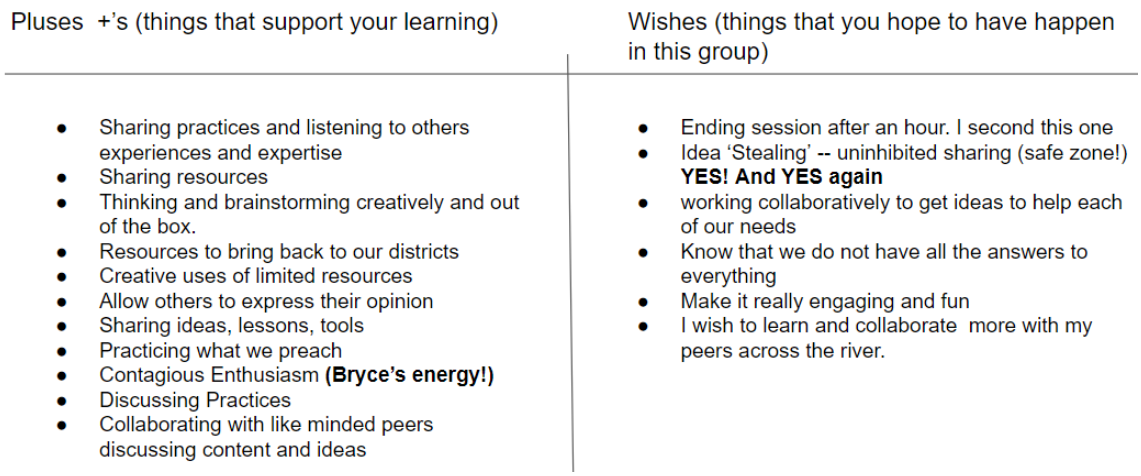
Throughout the design and facilitation of the community of practice, I carefully considered my own equity practice and attempted to model equity as the facilitator. I wanted the professional learning opportunity to be a "unique forum for hearing others and being heard" (Settlage & Johnston, 2014, p. 70). Borrowing from Settlage and Johnson's (2014) model for structuring conversation between professionals, I facilitated a collaborative space where participants followed a protocol that allowed each individual to present their challenges as "problems of practices," and receive feedback that led to reasoning for a solution. Settlage and Johnston (2014) refer to these persistent challenges and proposed solutions as vexations and ventures, respectively.

Whenever possible I invited participants to collaboratively design the community of practice. For example, at the end of each pre-interview, I asked each participant their preferred date and time for the online meetings. We decided that Tuesday evenings from eight o'clock to nine o'clock was the most agreeable time to meet. The first session occurred on November 17, 2020 and included a welcome activity that provided each participant the opportunity to introduce themselves to the group. I prompted participants to create a virtual name tag with the name they wished to be called and their preferred pronouns. We took turns sharing name, location, subject, and grade levels taught, something interesting about ourselves, and a recent uplifting or inspiring teaching experience. As a way of setting norms and expectation for the group, each participant

contributed to a list of pluses and wishes. When others agreed with something that was listed, they added their enthusiasm by stating "YES" or "I second this one" as depicted in Figure 4.

Figure 4

Community Norms Expressed as Pluses and Wishes



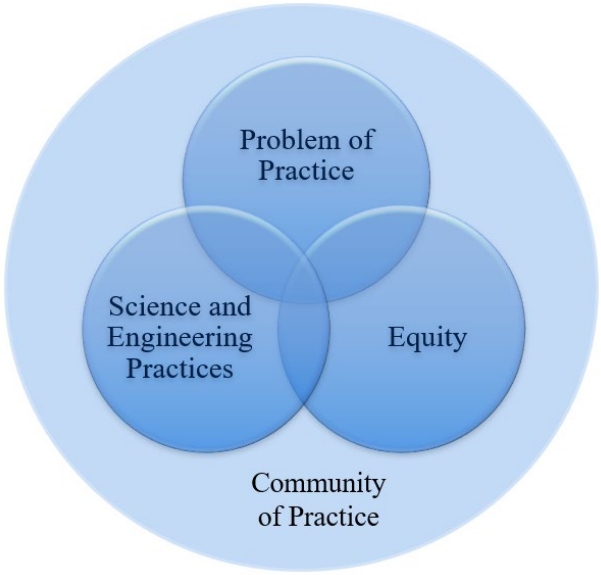
Pluses +'s (things that support your learning)	Wishes (things that you hope to have happen in this group)
• Sharing practices and listening to others experiences and expertise • Sharing resources • Thinking and brainstorming creatively and out of the box. • Resources to bring back to our districts • Creative uses of limited resources • Allow others to express their opinion • Sharing ideas, lessons, tools • Practicing what we preach • Contagious Enthusiasm **(Bryce's energy!)** • Discussing Practices • Collaborating with like minded peers discussing content and ideas	• Ending session after an hour. I second this one • Idea 'Stealing' -- uninhibited sharing (safe zone!) **YES! And YES again** • working collaboratively to get ideas to help each of our needs • Know that we do not have all the answers to everything • Make it really engaging and fun • I wish to learn and collaborate more with my peers across the river.

Note: Responses to other's comments are indicated in bold type.

At the end of the first session, I shared a diagram to focus the group on the topics of equity and the SEPs (Figure 5). My intention was to set boundaries for the discussion and selection of problem of practice topics that participants would choose for future sessions. I also presented a slide with a complied list of ideas about equity that participants shared with me in the pre-interviews. During session two, participants collaboratively discussed definitions of equity from the Framework for K-12 Science Education (NGSS Lead States, 2013). The methods used to facilitate discussions allowed participants to share their ideas in a space where they felt their voice was heard. They used any notetaking tool or diagram they wished to share their ideas with the group.

Figure 5

Focal Components of the Community of Practice



I introduced the concept of centering student ideas in our work as educators, calling on Larkin (2019), who states "student ideas are the raw material of our work" (p. 16) and asked participants to think about both why students' ideas are important and how to center students' ideas in the choices they made as educators. I briefly shared examples from *Ambitious Science Teaching* and provided resources for further exploration (Windschitl et al., 2018). In making these choices I invoked the literature from Design Principle One, attempting to ground the work in current theory on professional learning. In addition, I was careful to be responsive to participants' wishes. One of the goals stated in the pluses and wishes activity was "sharing practices" and "sharing resources." To address this goal, I created shared folders in Google Docs and encouraged participants to add resources and share ideas as they thought of them during meeting times, as well as times when we were not meeting.

At the end of session two, I briefly introduced the Tuning Protocol, which I called *Teaching with Attention to Equity*[4] (Appendix B). I asked that participants review it prior to the third session, during which we conducted a mock presentation. I presented a problem of practice and the group used the protocol to provide me with constructive feedback. Participants had the option of using my problem of practice as a template for organizing their presentations. Session two included time for questions about the type of problems of practice that might be best for discussion. Participants signed up to present beginning in session four. On most dates, two participants presented (Table 3).

Throughout the discussion and framing of how we were to use the tuning protocol, I intentionally used language that positioned the participants as knowledgeable professionals who had the opportunity to identify and work on something that was important to them in their individual teaching context. Despite this affirming approach, Eddie expressed concern over getting feedback on his teaching stating,

> I tend to take things a little personally and I know that we are in a group where we are respected, and we help each other out…but I am not sure how I would feel outside of this…I love the model…but how do we cope with that fear without feeling like we are attacked.

[4] The tuning protocol used in this study was modeled after McDonald, J. P., Mohr, N., Dichter, A., & McDonald, E. C. (2015). *The power of protocols: An educator's guide to better practice*. Teachers College Press. and Settlage, J., & Johnston, A. (2014). The crossroads model. *Educational Leadership, 71*, 67-70.

Table 3

Schedule of Tuning Protocol Presentations During Weeks Four Through Week Nine

Week	Date	Name
4	December 8	Tom* Carisa*
5	December 15	Lucy Penelope*
6	January 5	David*
7	January 12	Eddie* Joyce
8	January 19	Kathryn* Alana*[5]
9	January 26	Bryce*

Note. The problems of practice presented by participants noted with an asterisk * are discussed in Chapter Five.

Eddie related his concern to his experience with administrative oversight in his district where he often felt defensive when receiving feedback about his teaching. Carisa and Lucy both shared that they had experience with protocols, like the one we were using, in other professional learning communities and had success with them. They offered Eddie comfort by stating that the protocol guides the process of improving teaching collaboratively and respectfully. Notably, when asked to reflect on the structure of the community of practice sessions during the final interview, Eddie stated,

> The Tuning Protocol was an outstanding way for teachers to learn from teachers. I agree with Bryce's reaction, a quote from the Bible, Proverbs 27:17 "iron sharpens iron." Occasionally, instructional coaches are too removed from the classroom, so they cannot offer much practical support. I think having teacher's problem solve their own issues is conducive way to exchange ideas and grow from one another. In a way, it even parallels the SEPs.

The tuning protocol served as a boundary for the discussion by providing each participant equal time and attention in the community of practice space. I requested that each presenter make a statement of how the problem of practice connected to equity and to at least one of the SEPs and they had autonomy to select the specific topic and focus. Based on my professional knowledge as a teacher educator about what most teachers need and want from professional learning opportunities, and drawing from the literature, I encouraged participants to make their presentation time meaningful for their teaching (Reiser, 2013; Richman et al., 2019).

Two participants presented in four of the sessions (four, five, seven, and eight) and two sessions (six and nine) included one presentation. During the remaining time in session six, I shared examples of lessons that used specific practices to center student ideas and shared several resources for teachers to explore on their own time. To conclude session nine, I shared the link to a survey and invited the group to work with me in one-on-one sessions over the following two weeks to talk about how they might integrate the feedback they received into their teaching. The group decided collaboratively to meet again twice more to discuss how the community of practice influenced their ideas about equity and share the shifts they made in their teaching.

Participants' feedback regarding the tuning protocol provided evidence that the practice of structuring discussion and feedback in this professional learning space was positive and was recognized as an equity practice. Like Settlage and Johnston (2014), who reflected that their participants "feel safe letting down their guard and listening to new ideas and perspectives," (p. 70) I found that participants felt respected and showed respect for one another, and in many discussions succeeded in pushing each other beyond their comfort levels to encourage the uneasiness necessary for progressing through sensemaking.

Participants began the work of making sense of equity with various levels of understanding. They each engaged in the community to make sense of something puzzling– equity practice in the science classroom (Ball, 2009; Odden & Russ, 2019). Therefore, I noticed that participants' sense of purpose were important indicators of how they described equity at the beginning and end of the study period. In the following section, I share participants self-described sense of purpose as science teachers and their ideas about what attention to equity meant in their science teaching.

Sense of Purpose for Equity Practice

Participants' interest and willingness to participate in this study is an important factor when considering their sense of purpose for engaging in equity focused teaching. All participants volunteered for this work, responding to the call to "engage in a community of practice" and share "challenges and solutions specifically around the science and engineering practices (SEPs) and attention to equity in teaching" (Appendix A). By volunteering, participants expressed purpose in learning with others and improving their teaching practice. As a group they had some

experience with the concept of teacher agency and classroom leadership[6] in prior work with the GenerationSTEM and BioSTEM programs.

Teachers acting as agents of change believe that their professional roles include implementing practices that improve educational opportunities for students (Biesta et al., 2015; Pantić, 2017). Those acting with a commitment to social justice pursue practices that include all students (Li & Ruppar, 2021). The process of learning to teach with practices that accomplish goals of inclusive and equitable education begins with making individual beliefs about teaching explicit (Bryan & Atwater, 2002). Therefore, to begin the work of becoming equity-focused educators, individuals must interrogate their own beliefs and biases about issues that historically present barriers to inclusion in classrooms and be thoughtful about how equity fits into their sense of purpose as educators (Li & Ruppar, 2021).

The personal qualities and beliefs of educators is a significant factor in determining teacher agency (Biesta et al., 2015). Analysis of data revealed that participants held specific beliefs about their individual purpose as educators, articulated through responses to questions about teacher identity and about the role of equity in the classroom. Most participants described their professional role through the lens of facilitator of learning. Facilitation, as opposed to leading or directing, is a goal of reformed teaching in science classrooms and participants descriptions aligned with reform language (Reiser et al., 2017). In the following pages, I share participants' individual and collective ideas about equity and communicate the five themes that emerged.

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[6] The final requirement in the GenerationSTEM program was to design and implement a professional development project. The program encourages teacher leadership from teachers' position in the classroom, not positions in administration.

Defining Equity

An understanding of teacher's ideas about equity serves two functions. First, the data revealed the varied ways in which equity can be conceptualized within a small group of educators. Second, initial ideas served as markers for noticing the inconsistencies between how participants talked about equity and how they described their teaching. During the first community of practice session, I presented anonymous statements made by participants in pre-interviews regarding their ideas about equity. My intention was to establish a starting point for our collective thinking. By showing all ideas, the group was able to see the variety of responses and look for similarities and difference across responses (Figure 6).

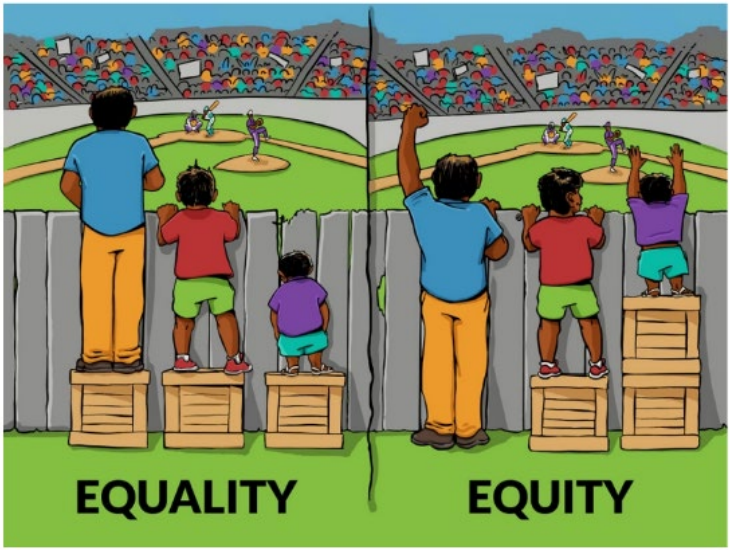
Figure 6

Participants Initial Ideas About Equity

In addition, I shared an image that both Tom and Eddie reference to communicate their ideas about equity (Figure 7). The figure was not created by either participant but used to help communicate their ideas about equity. Using visuals helped participants articulate many of the ideas they shared above and then elaborate with examples from their teaching.

Figure 7

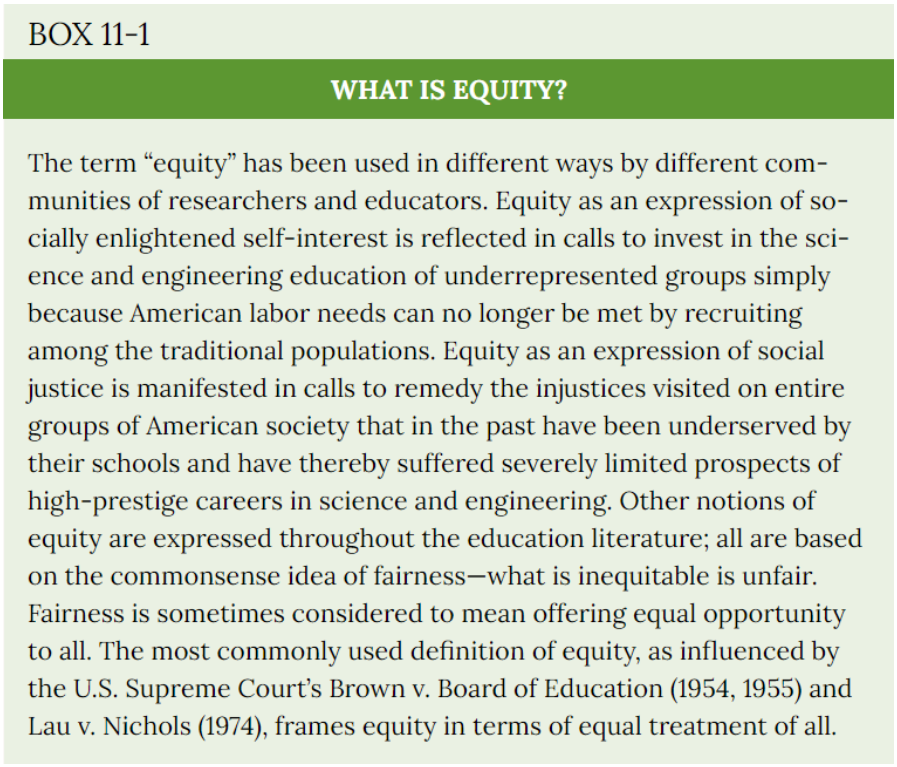
Visual Ideas about Equity Shared in the Pre-interview (Craig, 2020)



During the second session, I reiterated the expectation that as a community of practice we would proceed recognizing that we each held different perspectives on equity, taught in a variety on contexts, and would treat the space as a place to explore ideas collaboratively. We reviewed the NGSS Science and Engineering Practices, and in small groups responded to the definition of equity provided by the Framework (Figure 8).

Figure 8

Definition of Equity from the Framework for K-12 Science Teaching (National Research Council, 2012)



BOX 11-1

WHAT IS EQUITY?

The term "equity" has been used in different ways by different communities of researchers and educators. Equity as an expression of socially enlightened self-interest is reflected in calls to invest in the science and engineering education of underrepresented groups simply because American labor needs can no longer be met by recruiting among the traditional populations. Equity as an expression of social justice is manifested in calls to remedy the injustices visited on entire groups of American society that in the past have been underserved by their schools and have thereby suffered severely limited prospects of high-prestige careers in science and engineering. Other notions of equity are expressed throughout the education literature; all are based on the commonsense idea of fairness—what is inequitable is unfair. Fairness is sometimes considered to mean offering equal opportunity to all. The most commonly used definition of equity, as influenced by the U.S. Supreme Court's Brown v. Board of Education (1954, 1955) and Lau v. Nichols (1974), frames equity in terms of equal treatment of all.

Using the breakout room feature of Zoom, participants divided into three groups based on grade level (elementary teachers: Joyce, Kathryn, Lisa; middle school teachers: Eddie, Carisa, Alana; and high school teachers: Bryce, Tom, Penelope) and responded to the definition of equity as written in the Framework. Groups selected notetaking tools, or diagrams, as they wished to share their ideas with the group. For example, the high school group presented a collaborative online document using the online tool Jamboard to represent their ideas. Together we identified some of the concerns we had about the definition provided in the Framework. I shared that others in the science education community also critique existing definitions of equity and are working to understand how equity practices are enacted in classrooms. For example, I shared a summary of Philip and Azevedo (2017) who argue that the equity stance maintained in NGSS falls short of

what is needed by maintaining the status quo, framing underrepresented groups as instrumental in filling voids in the STEM fields, taking a colorblind approach, and attempting to erase past injustices rather than acknowledging them. As a group, the ten participants identified important missing components of the NGSS definition, including the importance of an intersectional lens on identity. Participants shared personal experiences with addressing equity in their teaching and their personal lives.

Overall, the group expressed an inclusionary approach to equity, taking personal responsibility to make content meaningful for all students (Calabrese Barton & Tan, 2020). For example, David used NASA mission scenarios to engage students and Tom shared his personal adventures. They shared the goal of removing barriers to learning, exemplified in David's statement:

> Equity means that no matter who the student is, they are able to achieve success in whatever we are doing. And I think success is different for different students. Students should not feel constrained by their race, culture, gender, socioeconomics, or their ability level when approaching a project…this is hard to do.

Participants ideas about equity aligned with current literature, notably Windschitl and Calabrese Barton (2016) who define equity in classroom instruction as "providing opportunities for all students to learn challenging ideas, to participate in the characteristic activities of the discipline, and to be valued as important and fully human members of the science learning community" (p. 1101). In the following pages, I unpack the specific themes that emerged when analyzing how participants talked about equity with respect to their teaching practice. First, participants expressed the importance of being a facilitator of knowledge development, rather than the keeper of knowledge. Second, some participants articulated the importance of building respectful

relationships with students so that they feel that they are valued members of the classroom. Third, teachers discussed their roles as advocates for their students. Fourth, participants spoke of fair access to resources and quality teaching and lastly, participants discussed equity teaching as knowing how to connect to students lives through content and pedagogical choices. Participants varied descriptions of equity align with Brenner et al. (2016) and Darling-Hammond et al. (2019) who explore multiple definitions of equity represented in the literature.

Equity as Facilitation of Learning. As Reiser (2013) state, teaching in NGSS-based classrooms requires that teachers shift from "simply present(ing) facts and definitions as ends in themselves" to "help students continually work toward explanatory models, developing these ideas from evidence" (p.4). Teachers are expected to support student's explanation of phenomena. Participants each articulated their role as facilitator, using specific examples from their teaching contexts (Lynch, 2000).

Both Penelope and David used the analogy of inviting students on a learning journey. Penelope shared, "I sometimes tell my class that studying chemistry is entering a new world… the periodic table, and we are exploring that world. And of course, I do know a little bit more about some aspects of world then they do. So, I guess I am the lead explorer. But there are also things that I don't know, and we explore together." Eddie explained that he loves "getting messy with students" and "diving into phenomena and investigations." Lucy described herself as a student-centered educator and emphasized respect for all her students as a central part of learning. She shared that she sees her role as someone who strives to create a respectful student focused learning environment.

Carisa believed in empowering students by helping them to be successful and understand why learning is important. She expressed that many of her students do not recognize their

potential. As a bilingual educator working with students who are all Spanish speakers, Carisa valued using native language to help students understand science. Tom suggested that every student has something to contribute, and it is his "job to crack into how they learn it." He explained that he takes on the challenge of "engaging and entertaining to keep students in the classroom" where he can support them. Similarly, Kathryn and Jodie both used the analogy of "being a bridge for students." Jodie emphasized the importance of representing the real-world cross curricular nature of learning in all her lessons and helping students see the connection between disciplines. Kathryn articulated a responsibility for exposing students to opportunities and experiences to which they do not otherwise have access. Her dedication to supporting her students was evident, however, she felt responsible for introducing them to science because they "will never have the opportunities to experience the science outside the classroom." Her vision of how students related to the content was based on her observation that, "students never draw themselves as a scientist. They don't see themselves in a position where they think they could have a career in STEM or science." She described perceived barriers for her students stating, "many are immigrants and do not plan to go to college because they fear getting in trouble. Students are from immigrant families where there is a language barrier, and the parents don't see themselves in STEM fields."

Bryce approached teaching as an advocate for his students and leaned heavily on his own experience and identity as a resident of the community he taught in to support his student's development. Bryce stated, "I teach science as a language, and I know that I have to be the translator of scientific language. I use my hood language with my science language−I am that mediator."

Taking a different approach than the others, Alana shared a strong commitment to content knowledge. She stated, “I feel more emphasis should be given to content when it comes to science and subjects like that because I feel unless you know the content, you will not be able to be in a field where you have to specialize.” Alana was the only participants who specifically focused on content knowledge over pedagogy. All participants articulated the goal of sharing the world of science with their students–that the activities they engage in together are meant to be a catalyst for understanding the natural world.

Equity as Respectful Relationships. Each participant had a unique teaching style, which came through in their presentations and interactions with one another. In their own ways, they recognized that building a culture of respect, support, and collaboration in the classroom was an important component of equity. David identified himself as the only Black male in his school building. He described himself as a role model and mentor to his students and reflected that his style of teaching and his relationship with his students afforded him the ability to be a better teacher. While he worked closely with his White male colleague to plan and implement lessons, he perceived that students had a very different relationship with him then they did with his counterpart. Students sought him out to talk about sports and music, not always science topics. David was keenly aware of his position as the only individual of color in his building.

Penelope and Alana both described a high level of support for students as an expression of positive relationships in the classroom. Penelope recognized that rigorous curriculum and her highly structured approach provided a caring and positive environment. She explained working with a student who was struggling in her class and overwhelmed by the recent shifts to remote learning brought on by the pandemic. Penelope worked with this student one-on-one and was able to help her manage her time so that she could be successful with the math component of a

chemistry lesson. She noticed, “through providing an organized classroom, where I am present, and I help the kids…I provide structure…and they know what they can count on when it comes to me. It helps them to open up.” She explained, “They're not mutually exclusive−teaching good content and being a good person for the kids.” After talking with the guidance counselor in her school, Penelope concluded that her positive relationship with the student she recently helped was instrumental in keeping the student in school.

Alana described a similar ability to work with students and develop relationships with those who attend her class.[7] She articulated how she made her content interesting to students by incorporating games and making connections to their interests outside the classroom to demonstrate that she “cares about them and wants them to get a good education.” She reported on specific instances where taking the time to develop positive relationships with students provided for a more inclusive learning environment. However, Alana recognized that these interactions happened with few students, especially during hybrid teaching, and she expressed the need to be able to reach more students who needed her support.

Equity as Advocacy. Participants who discussed equity with an advocacy stance shared varying levels of responsibility for making time in their classes to discuss political and social conversations about events happening in the world. As noted, this study took place during an unprecedented time of unrest in the United States due to the global COVID-19 pandemic and nation-wide demonstrations following the killing of George Floyd by a police officer. Participants addressed existing social and political events in very different ways.[8]

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[7] Alana reported a significantly low level of attendance during the pandemic.

[8] George Floyd, a 46-year-old Black man, was arrested and killed by police in Minneapolis, Minnesota on May 25, 2020.

Penelope's participation in the community of practice started in the midst of what she referred to as her "year of learning." Prior to beginning this study, she engaged with a group at her school where she and colleagues were looking to "validate student voices." She shared "I feel like my awareness of equity and inequity has increased and I am getting a heightened sense of inequities in several areas." Being part of the community of practice was part of that process as well as reading and reflecting on inequities in schools and society. She shared that topics "weigh heavy on her" and she had to take it slow. Penelope recognized that making sense of equity is a process, "I feel like things are changing in me, but I know it takes time. I feel like I've lived in oblivion for quite a while. I wasn't aware…that's not a good excuse. I've had a blind spot, I guess." She recognized the privilege of her choice to recognize equity, stating, "as a White female, you can easily choose to not pay attention to the issues." She explained, "equal distribution or access to good education has always been something that has been on my radar." In her teaching career she had specific experiences where students from very diverse backgrounds and socioeconomic situations had come together to learn science. These experiences were inspirational for her. In one example she described two students, one from an inner-city school and the other from a very prestigious private school, who attended the same summer program and developed a "wonderful working relationship." She recalled thinking of science at that time as "an equalizing opportunity."

There are two ways that Penelope articulated responsibly to advocate for her students. First, she indicated that she would continue to learn and seek information. She would "speak up in her school for People of Color, for international students, for individuals in the LGBTQ[9] community." She shared her dedication to supporting students and to working towards a school

environment where their voices would be heard. Penelope shared, “When you are White and you read about racism, nobody goes without blame.” She elaborated, “you have to be super uncomfortable with the fact that this is the society that we created and decide what you are going to do with the future. You cannot change the past, but you can act for a better future.” Like Penelope, Alana felt strongly about advocating for her students but felt powerless to do so within her school structure. She identified concerns with students not attending classes and described her administrators approach to the problem. During the time frame of the study Alana was responsible for completing final grades for the semester. She explained that the majority of her students were failing her classes. She was instructed by her administrator to create two assignments for students to complete in the final week of the semester so that they could pass the class. Despite her disagreement with administrators, Alana complied. In the community of practice session, she expressed the desire to advocate for a better education for her students but perceived that she lacked the power to do anything. Her perception was that the school was “spoon feeding them” and just passing students through the system without making sure they learn. Despite attempts to discuss ways to support students, Alana reported being dismissed by administrators, leaving her feeling powerless to advocate for the education she believed the students deserved. Overall, the data revealed that participants wanted to be advocates for their students, however, contextual factors influenced the ability to do so.[10]

Equity as Access. Equity described as access included quality education from a socioeconomic perspective, including access to materials and resources. Lucy and Alana focused on disparate allocation of resources and materials. Alana recognized disparities between

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[9] LGBTQ is an acronym for lesbian, gay, bisexual, transgender and queer or questioning.

resources that she and her students had compared to other communities, like the one in which she lived. She specifically noticed computer access, time and materials for STEM clubs, and financial support for those activities from administrators who have the power to decide where funds are allocated. Alana shared,

> Education should be given freely to everyone. I know that there are clubs and all easily available in other districts, but my students don't get any of these. The type of education and the quality of education is not the same. I think people who are here get a very low quality of education, compared to the students who are in the community I live in. In a country like America where we have so many resources, things should not be this way.

Alana's recognition of socioeconomic disparities between school districts is well-documented in the United States (Darling-Hammond, 2001, 2013). Tom expressed similar observations and described his desire to support students whom he recognized might be impacted by socioeconomic disparities outside the classroom. He shared, "I am seeing that social economic gap and leaning into it to raise those kids on an equal playing field. That is probably the hardest part of my job." He recognized socioeconomic difference with his students and focused his attention on students who he believed needed additional support because of their socioeconomic status. As the community of practice work unfolded, Tom was able to explain that he focused attention on students who he identified as needing additional support.

Equity as Connections to Students Lives. Participants agreed that students' everyday lives and cultural experiences played a significant part in learning. They each elaborated on this idea in different ways, articulating their belief that it was their role as the teacher to bridge

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[10] The context for this study is important, as teachers were also focused on how to transition to remote learning while maintaining the integrity of their teaching.

content with aspects of students' lives. Carisa focused on individual students when thinking about equity. Sharing stories of working with struggling students from within a system that she felt did not support these efforts, Carisa articulated both the rewards of supporting students and the frustration of noticing the way her colleagues dismissed students who needed them. She shared, "equity is trying to reach out to those kids, even if it makes you uncomfortable or even if you don't think you should be doing it." Carisa shared several stories of working within an education system that she perceives does not address students' needs.

David referred to popular culture and current events as an entry point for getting kids excited about science. He described that he often sets his lessons up using a story or a scenario to engage his students. For example, he described a rocket launch activity with his seventh-grade class. He began by telling students that NASA called and asked them to design a rocket with specific criteria. Students were tasked with designing, launching, and collecting data on the rocket trajectory. David intentionally positioned his students as engineers and shared the career paths of professional Black and Brown scientists and engineers at NASA. He wanted his students to see themselves as scientists and engineers. David's goal of representing a diverse STEM workforce in his lessons and making sure that students engaged in the practices of science and engineering is a central goal of the NGSS (NGSS Lead States, 2013).

Similarly, Penelope described barriers that she noticed with her students that keep some students from making meaningful connections to content. She recognized, "some students come to my class already convinced that they can't do math and science." She observed this mindset across all cultures. In addition, she recognized that students are "reluctant to embrace science because of a perceived conflict between science and faith." Penelope articulated her vision of removing artificial boundaries to science and math content that are often perpetuated through

messages that students receive both outside of school and in school. All participants shared efforts to find connections to student's everyday lives. They were all eager to share new ideas, resources, games, and online teaching tools to make connections for students.

Analysis of participants ideas about equity demonstrate the complexity and interconnectedness of ideas across the various aspects of teachers' daily responsibilities. Participants articulated similar sentiments as Calabrese Barton and Tan (2020) who describe common approaches as "equity as inclusion" (p.343). Some participants discussed pedagogical approaches to equity by sharing their personal accounts of what they do in the classroom to consider all students. In Chapter Five, I explain how the group explored equity through structured community of practice presentations and feedback using the tuning protocol. I attempt to represent the dialogue between participants, the push and pull, that led to uncertainty and opportunities for participants to confront their activities in the context of improving equity practices (Allen & Penuel, 2015).

Problems of Practice–Making Sense of Equity Through Structured Discussion

Sensemaking is a dynamic process that requires reflective thinking. Collaborative discourse is a valuable component of the work required to figure out new ideas and ascertain the "mechanism underlying a phenomena in order to resolve a gap in one's understanding" (Odden & Russ, 2019, p. 192). Making sense of new ideas requires recognizing that what is new may be in conflict with existing knowledge and negotiating what to do with the discrepancy. I was interested in learning where teachers began the process of thinking about equity and how interacting with others in a community of practice influenced their understanding of equity focused practices. Therefore, I inductively identified the tensions between teachers' expressed ideas about their teaching and the examples they selected to work on with the group. The

analysis revealed that in some cases teachers identified with an equity lens but enacted practices that did not align with equity. Framing these inconsistencies as productive tensions suggests that the work is generative and that learning to teach with an equity lens is continuous (Ball, 2009; Thompson et al., 2015).

I focused my analysis on problems of practice presented by seven of the ten teachers engaged in the community of practice. I elected to omit three problems of practice because they focused primarily on concerns with how to distribute materials and resources during remote instruction. The focus on equity and the SEPs for each of the seven participants is described in Table Four. A description of the specific discussions that took place in the problem of practice presentations is presented in Chapter Five.

Table 4

Participants' Emphases on Equity and SEPs in their Problem of Practice Presentations

Participant	Equity Focus	SEP focus
Carisa	Supporting students with synthesis of the engineering design process.	Planning and Carrying Out Investigations
Tom	Social emotional learning	Planning and Carrying Out Investigations
Eddie	Encouraging students to support or refute claims.	Engaging in Argument from Evidence
Alana	Developing students' scientific writing skills	Analyzing and Interpreting Data; Constructing Explanations
Penelope	Encouraging students are challenged by abstract math	Using Mathematics and Computational Thinking
David	Supporting all students with hands-on chemistry learning at home; access to resources at home	Planning and Carrying Out Investigations
Bryce	Engaging students in Activism	Analyzing and Interpreting Data

Chapter Five: Findings from the Community of Practice

In the following section, I provide a brief overview of each participants' context and problem of practice focus. Then, I present segments of discussion that demonstrated critical moments in individuals sensemaking processes. I describe occurrences where participants noticed inconsistencies and reasoned with them through dialogue with their peers. As the researcher and facilitator engaged in the community of practice, the way in which I listened and responded to participants individual ideas, and their dialogue in community of practice dialogue was important. My process of making sense of the ideas, needs, concerns, and aspirations of the participants played a role in how I facilitated the group and contributed to the outcomes of this segment of the work. In the sections labeled "researcher notes" for each participant, I draw attention to the specific observations and moments of dialogue, both one-on-one interview discussions and community of practice dialogue, that I responded most deeply to when understanding and responding to participants sensemaking processes about equity.

Adhering to research-based practices in qualitative methodology, I engaged in member checking with participants to ensure that my interpretation of occurrences of noticing and reasoning process aligned with their ideas and recognition of critical moments in the discussion. When participants demonstrated shifts to their teaching as a result of community of practice discussions, I describe them as examples of planning or enactment. In some cases, participants shared plans for enacting new ideas but were not able to do so within the time frame of the study. Looking across participants problems of practice, I recognized productive tensions that became important markers for sensemaking. I conclude this chapter by outlining productive tensions in preparation for discussing the findings and the implications within the field in Chapter Six.

Carisa–A Problem of Supporting Student's Synthesis of Ideas

Carisa shared a unit plan on Newton's Laws of Motion to demonstrate a recent unit from her teaching and to focus the group on her problem of practice, which she called "how to support students with showcasing their decision-making process in an engineering design challenge." The specific SEP she addressed was *Planning and Carrying Out Investigations*. She wanted students to improve their ability to articulate their design process and outcomes when engaging in an engineering design challenge where they designed and built a rocket and related the engineering process to the laws of motion. She provided students with the anchoring phenomenon for the unit because she observed that "students don't have experience to draw upon, so I give them the phenomena as a starting point for the whole group." Carisa explained that her unit plan was very guided, included sentence starters and instructions for students to support their use of language. The unit assessment was intentionally less guided and required students to make connections and articulate their ideas independently.

Carisa's students were all Spanish speakers, some who she perceived were not able to express their knowledge or synthesize their science learning in their native language or in English. She described the school administration as "inflexible regarding how students organize their work and their data in daily notebooks." She perceived that for her administration "students with English Language Learner classifications are not a priority" and described students "with literacy deficiencies that are not addressed." She explained, "Some kids come to the school illiterate and are put into programs that are supposed to help them learn content but without a language foundation the programs do nothing for them." She described a system where students are not supported, they drop out of school, attend night school, and eventually drop out of school all together. She said, "I can pinpoint the kids who are going to drop out by tenth grade." The

group asked Carisa specific questions that led to her noticing aspects of her practice and opportunities to make shifts to her teaching:

> Penelope: It sounds like you have a fantastic engineering design project. Do your kids have a choice in how they present the project?
>
> Carisa: I'm always trying to have them make choices I because I feel like there is buy-in there. I will always choose allowing them to choose rather than to me for me to impose. I like the idea of a choice notebook… It's just that…In my school they impose binders–one for the morning, one for the afternoon–So, I don't know how well that's going to go for my classroom.
>
> Kathryn: It sounds like you're giving students a lot of choices, but they are having trouble synthesizing. Maybe condensing all of the ideas that you have and putting it in a format where they can visually see the different ideas would help.

This dialogue inspired Carisa to think about ways to scaffold the engineering design challenge so that students had a summary of ideas to pull from when doing the assessment, which she hoped they could complete on their own.

Bryce asked Carisa two additional questions that disrupted her ideas about students preexisting knowledge and experience. She revisited these conversations several times throughout the sessions as she grappled with her own ideas about equity:

> Carisa: The is the biggest issue is the writing. I always have that issue with the kids, even though I give them prompts, even though I give them guiding questions, even though I tend to do it in English or Spanish, it does not matter. They still struggle with putting it all together.
>
> Bryce: Are they language enhanced students? Do they know both English and Spanish?

> Carisa: Some of the students have interrupted education. All of them speak Spanish. Most of them have very low levels of literacy in their native language. Even with all those supports (prompts, sentence starters), I get very little response from students.

Carisa's response to Bryce suggested that she may not have considered students ability to speak in two languages as a positive asset. Bryce's use of the term "language enhanced" suggested an asset-based approach to language, which was noticeably different from the way Carisa spoke of students' language in her problem of practice presentation.

The next notable moment occurred as Bryce suggested that the use of the rocket in Carisa's engineering design challenge was part of an "old paradigm in science teaching." Bryce suggested that by imposing the rocket as the phenomena the lesson had a "Eurocentric approach" and did not consider the students in the classroom and their experiences with the concepts of Newtonian physics as well as it could have. Bryce suggested "it will be more interesting if they can interpret events in their lives that demonstrate Newtonian physics." Bryce proceeded to use an example of a lesson on filtration that he modified to focus on students' ideas rather than the prescribed ideas about the content from the school mandated curriculum. This example became as a frequent point of discussion for the group.

Carisa responded that she had never thought of her teaching from a Eurocentric perspective and wished to know more. She promptly investigated on her own and reached out to Bryce and me for additional conversation. Final interview data revealed that this moment was significant for Carisa as she reasoned with ways to develop her understanding of systemic inequities. She shared, "I'm more inclined to think about how my practice can be shaped to bring in more of my student's ideas and background. My biggest take away was Bryce's comment on Eurocentric teaching practices. It definitely hit a nerve, a good nerve."

Carisa−Noticing Language Assets. Two notable occurrences resulted from Carisa's problem of practice. First, Bryce's use of asset-based language to describe student's ability to speak in more than one language contrasted with the deficit language Carisa used to describe student's language abilities. This moment stood out as an important marker for talking about students' abilities in the group and once Carisa became aware of her language use, she made efforts to adjust. Second, Carisa's "eyes were opened" to knowledge of Eurocentric teaching practices that position White culture, practices, and individual's contributions to science in curriculum. These terms and ideas were not part of her teacher education or her professional learning until this time. The dialogue presented a productive tension that inspired interest in historical inequities in education. As an individual who felt she worked very hard to individualize instruction and go above and beyond what was required to support student's needs, Carisa became very interested in learning more about inequities and immediately decided that she would explore further.

Carisa−Enactment of Summary Tables for Supporting Student Synthesis. During the final group session, Carisa articulated how she adjusted her teaching, including units that involved design challenges, to include summary charts. She adapted this practice from the *Ambitious Science Teaching* resources shared in the group sessions (Windschitl et al., 2018). She explained "summary tables will be a good tool to help students process information before I asked him to reflect on it at the end of the unit. I really want them to reflect about what the lesson was supposed to teach…what was the idea behind the design challenge. It is not just to build something, like a toy, you know, the idea is to learn something from it." She described how summary tables would help students synthesize all the activities in the unit and shared two examples of tables created and used with students in the weeks immediately following her

community of practice presentation (Appendix E). The first example was from a module on the topic of evolution. The summary tables organized key ideas from nine activities in the unit under the headings: 1) What do we observe? What do we notice? 2) What is causing these patterns of observations? What does the data say? 3) How does this help us understand the evolution of living things? The second example Carisa shared focused on organizing ideas from five activities focused on wildfires, using the same summary questions. In the final group session and post interview, Carisa shared that the summary table strategy was helping students synthesize the unit and understand the overall purpose of the activities. She looked forward to using the strategy in future units, as she recognized it to be a supportive practice for all her students.

Carisa−Researcher Notes. When I listened to Carisa speak of her students it was apparent that she cared deeply about their success and strove to help them learn science by using the abilities they had, including their bilingual skills. As a Latina, bilingual educator Carisa recognized many of the challenges of supporting language learners in a school system that valued English over other languages. She made choices to support students in both their native language as well as in English, despite her administrator's requests. She expressed frustration with the lack of resources and support available to students within the education system, not with the students themselves, saying "I am constantly saying that the reading level that our kids read at is very low. I'm not saying it as a complaint. I'm saying it as a matter of fact, so I need resources that can help them understand." Carisa explained that instead of forcing students to learn only in a foreign language, teachers can appreciate where students come from and allow them to be proud of their native language. She believed that students can be part of different communities and articulated the complexities that parents and families face when trying to support their children who are being educated in a different language and culture than their own.

She spent hours translating documents and seeking resources to support students understanding of science. The use of summary tables is an example of an additional tool she selected specifically to support language learners.

The misalignment between the way Carisa talked about teaching and the way she referred to her students was so striking to me. I noticed that despite articulating an affirming view of students and their language assets, Carisa used deficit language to talk about her students, saying that English Language Learners in her classes have "speech and language deficits" and have "low" reading levels. I noticed that initially she did not realize that her deficit language did not represent her encouraging view of what her students were capable of achieving. As the facilitator, I had to make decisions about how to address deficit language use in the group. I chose to provide opportunities for other community members to reflect and ask questions of one another first, before highlighting the tension. By engaging in dialogue with others in the community, Carisa became aware of her use of language and took up the challenge of learning about systems in place within schools that result in the struggles she described as a teacher. Carisa's problem of practice and post-interview data revealed that she started on a journey of learning about Eurocentric practices and was intentionally thinking about "starting units differently, with a focus on student's ideas" after listening and reasoning about why this shift in her approach was important for her students. Her use of the summary tables as a supportive tool for English Language Learners and her attention to her language emerged as two focal points of sensemaking about equity.

Eddie–English Language Learners Using Evidence to Support Claims

Eddie presented a lesson for his seventh-grade class focused on the chemistry concept of burning and provided students with three claims from the district's required curriculum, *Pursue*

STEM. The goal of the lesson was for students to provide evidence to support or refute claims after engaging in specific activities. The focal SEP was *Engaging in Argument from Evidence*. Eddie's presentation focused on a variety of different topics, with the main focus on supporting students with the claim, evidence, reasoning format for communicating their science ideas. Eddie shared a general statement on equity, expressing his goal of "reaching students who struggle with the content" and began with a statement to focus the group on his problem of practice:

> I strive for multiculturalism and social justice connections in my lessons; however, despite the fact that it increases engagement and awareness, it does not build mastery of skills. I am unsure on how to implement strategies that helps students with special needs, and what that will look like in the classroom.

Eddie repeatedly stated that he focused on exploring multicultural connections to content. However, there were inconsistencies between Eddie's recognition that "multicultural connections" increase engagement and his statement that they "do not build mastery of skills." He referred to a book he recently read about culturally responsive teaching and used terms like multiculturalism, social justice, engagement, awareness, and mastery of skills in his presentation. Eddie struggled to make connections between these ideas, an indication that he was making sense of what they meant, why they were important, and how the concepts supported his teaching practice. For example, when Penelope asked him to clarify what mastery of the claim, evidence, reasoning skill looked like for students in the lesson, he responded, "I rely on what the NGSS says. I don't focus on the language arts or math standards and, you know, honestly, I do not know."

Eddie's problem of practice provided opportunity for group members to engage in dialogue about practices for supporting English Language Learners. Eddie's students were 76% Hispanic, and most were English Language Learners. His presentation included specific data

showing that students did well on state math and English exams compared to state averages. Members of the group provided Eddie with suggestions for professional development, such as the Sheltered Instruction Observation Protocol (SIOP) Model that specifically discuss practices for supporting English Language Learners. Carisa, also a teacher of English Language Learners asked Eddie about his approach to supporting language development:

> Carisa: Do you happen to know if your students are literate in their native language? Do you ever give them the opportunity to respond in their native language? I mean, some kids may not know how to write in their native language.
>
> Eddie: I have a language coach and I worked with him very closely. He tells me all the time that it's frowned upon (to speak Spanish). My first thought was, oh, I speak Spanish. This will be a breeze. This will help the students. But that's really frowned upon when you're trying to build the skills for them to learn in English. We want them to speak and write and read in English. If I'm just constantly saying things in Spanish… it's helpful… but am I really building those skills?
>
> Carisa: I know what you're saying, but I'm the complete opposite. That is why I asked. Because I know that approach and I always have to battle that approach. I get it, but I have another side of the story.

Eddie told Carisa, "I agree 120% and I would love to do those things in my classroom, but I still have to do the things that will help my students with the content." In the final interview Eddie shared, "if (a student) is reading three grade levels behind, social justice teaching is not going to do much to accelerate that."

Eddie−Noticing Conflicting Approaches to Language Support. Through careful review of Eddie's problem of practice, it was clear that the statements he made when describing

his identity as a teacher interested in equity practices conflicted with the practices he used and was coached to use in his school. I interpreted that the language Eddie used and the inconsistencies in his presentation as evidence of his sensemaking process regarding practices to support English Language Learners. As a self-identified Latino and Spanish speaker, he was encouraged by his supervisor not to speak to students in their native language. Eddie grappled with what his school district coach required, what he observed in his classroom, and what made sense to him with respect to supporting English Language Learners understanding of science content. His approach was consistent with his originally stated ideas about equity, where he shared that all students should have the "same policies and the same education." Eddie did not acknowledge the influence of race, culture, and language on student's ability to learn science concepts. The feedback he received led to him contemplate "sameness" and the value of supporting student's native language when teaching science.

Eddie−Enacting Practices that Broaden Student Choice. Eddie made immediate shifts to his teaching following the community of practice sessions. When planning for and implementing a unit on Energy and Matter, he reported thinking about ways to make content more relevant to students because of the COP discussions. Eddie adjusted a lesson on "how carbon dioxide moves in and out of abiotic and biotic factors through photosynthesis and cellular respiration" by allowing students to investigate local impacts of carbon dioxide levels on pollution. Students analyzed three maps including pollution levels, tree canopy gaps, and asthma hospitalization rates among children and discussed if there was a correlation between the data sets. Then students designed an informational media piece of their choice to inform the public about the rise in carbon dioxide levels and the impacts the community. Eddie collaborated with his colleague in the art department, who focused on design and graphics for the public service

announcements. Eddie reported “Some students focused on the effects of deforestation globally instead of locally– but that's ok. They were free to choose as long as they included authentic data from a reputable source.” He looked for student’s ability to describe how carbon dioxide levels were regulated through photosynthesis and cellular respiration. They had the freedom to select a location to study and a format to communicate the information.

Notably the student example in Figure 9 included use of both Spanish and English to communicate content in a public service announcement. Eddie described student’s eagerness to communicate in both languages because they recognized their audience would benefit from access to the material. In the post interview he shared that he started allowing students who struggled with communicating their ideas by writing in English to record themselves and share their ideas verbally and visually. This is a notable shift to his original stance on students using their native languages to talk about science ideas. Through dialogue in the COP sessions, Eddie reconsidered the way he supported English Language Learners. He shared that he had expanded his thinking about equity and had not been considering the importance of native language in learning new ideas in science.

In the post interview, Eddie shared that he was planning his lessons thinking about how students’ ideas were represented. The student example demonstrates his shift to thinking about language as an important aspect of students’ knowledge development and by giving students choice in how they presented content, he was valuing their language identity and as he shared, “considering how they are getting a voice in the lesson.”

Figure 9

Eddie's Example of Student Work

Eddie−Researcher Notes. Throughout discussions with his colleagues and in the individual interviews, Eddie seemed to be struggling with how to represent his approach to teaching, which indicated to me that he was trying to make sense of the many messages coming to him from his administrator, the literature he was reading, and interactions in our community of practice. Eddie's statement regarding culturally responsive teaching, where he said, "despite the fact that it increases engagement and awareness, it does not build mastery of skills" indicated that Eddie was trying to make sense of how culturally responsive practices supported student learning. In addition, he was unsure of how to negotiate what he thought was good teaching practice and what his administrator requested of him. As the facilitator, I noticed Eddie trying to make sense of a variety of conflicting ideas and decide how to proceed. I observed that Eddie lacked confidence as a new teacher to push back against what was being asked of him by his administrator, but that he was interested in learning and implementing practices that would help his students. Eddie's willingness to give students the option of writing in their native language in the lesson that he shared, demonstrated that he was able and willing to try new approaches.

Alana−Problem of Improving Students' Scientific Writing Skills

Alana focused her problem of practice on improving her students scientific writing skills, stating that her eighth-grade students "struggle with reading and writing" and were "below grade level in math and English." She wished to discuss with the group how to support students with their argumentative writing skills and selected the SEPs *Analyzing and Interpreting Data* and *Constructing Explanations* as her focus. Alana noticed that her students struggled with providing scientific reasoning when asked to reason with evidence to support or refute a claim. She stated, "most of the students fail to write a convincing scientific argument even though they seem to understand the content when they express it verbally."

Alana was required to follow the district curriculum *Pursue STEM* and reported that her administration was strict about progressing through the curriculum on a dictated schedule. For every unit of study, the students had to write a scientific argument. The claims were provided in the curriculum.

The following dialogue introduced a new idea that group members, including Alana, individually and collectively grappled with:

> Bryce: I want us to think about just how we teach science. Is it prescribed or it is supposed to be an example of what we want the students to do? We want them to think through their processes, develop their own claims, gather their own evidence, and then think through that, and reason through that evidence. If we are providing claims for them how authentic is the value of that science? Is that access? Is that equity?
>
> Lucy (directed to Alana): Do you have the ability to do self-guided instruction with students? For example, can you have students co-create claims in class?
>
> Alana: I did before *Pursue STEM.*
>
> Kathryn: Sometimes our curriculum is imposed upon us.
>
> Bryce: In my experience a new administration might come in and they might be interested in a different initiative. For example, (in my district) they feel that Black and Brown students can't write, they can't read. So, what do science teachers have to focus on? The writing and reading…instead of the science. That's the battle that Alana is going through in terms of her science teacher identity. She is grappling with feeling like "I'm supposed to be doing hands on things. I'm supposed to have explorations. I'm supposed to be the fun one, but yet I am confined to this curriculum." My advice is (directed to Alana)…fight for your teacher identity… when people say, "Oh, we don't care about

science practice", you will say "look, you better care because my classroom is hot and my classroom is where the most inclusive practices are happening."

Kathryn: I agree Bryce. If you are going to save yourself as a teacher, you need to advocate for yourself, because no one else is going to do it for you.

Participants shared resources with Alana for scaffolding the claim, evidence, reasoning process. Alana grappled with feeling constrained by having to follow the *Pursue STEM* curriculum and articulated that she was no longer able to make time for the type of student-centered teaching that she wished to implement. The administrative pressure to teach in a specific way provided a clear conflict for her. The discussion about teacher identity led Alana to consider her approach to teaching claim, evidence, reasoning within the district curriculum.

Alana's Noticing–Gaining Awareness of Barriers for Equity Practices. Alana's goal of supporting students with equitable practices was in direct conflict with the practices she was required to implement in her school. She grappled with her ability to advocate for herself in her school and shared that she was not confident with student-centered pedagogy because her teacher education was very content focused. In the post interview, Alana talked about the specific barriers to enacting equity practices. She focused on frustration with her school administration for requiring her to follow a specific curriculum and for giving her poor administrative reports if she deviated from the curriculum. For example, at the time that we spoke, Alana had just finished working one-on-one with students who had not attended her classes in several weeks. She was required by her administrator to create and work with students on two assignments that would allow them to earn a passing grade. In addition, Alana was overwhelmed with the struggle to teach students science when she lacked language support for her large multilingual classes and

lacked support from her administration to teach using practices that she believed supported conceptual understanding.

Alana's Planning−Navigating Barriers with Determination. Alana's dedication to her students was evident despite the barriers and deficit approaches to education that she described in her teaching context. When Alana and I met to discuss outcomes of the community of practice session and our work over the 16-week period, she was overwhelmed by the time and effort it took to implement her administrator's request to pass her failing students. She directly addressed the conflict between her administrator's stance on passing students and her beliefs about equity. She shared these concerns by stating, "equity is getting the kids to show up" and "giving teachers the resources to help students who have identified needs." While she felt constrained by her current context and lack of support from administration, Alana recognized what she felt was the root cause of issues and identified several components of the school culture that could be addressed to improve the learning environment. She did not share evidence of enacting new practices within the study period. However, she did articulate plans to visit other classrooms to learn from colleagues. She hoped to connect with members of the community of practice who also taught in the same large urban district. Alana exhibited competency in her ability to recognize barriers and seek out opportunities to collaborate with others to achieve change.

Alana–Researcher Notes. As the facilitator of the community of practice, removed from each participants context and unable to visit schools or gain a perspective on the teaching environment for myself, I had to be mindful of the perspective that each participant shared and be careful not to pass judgement of my own. The ideas shared by each person was their truth, their lens on teaching and it was important to listen to and respect all ideas. When listening to Alana's description of her students, this stance became particularly important.

Alana had a strong sense of purpose for education. She believed that every student should be able to have a general understanding of the way the world works and that students should be getting the support they need, especially during difficult times, like the shift to remote learning. In addition, she felt that they should be held accountable for hard work. She shared, “how are you going to tell these kids that you have to face adversities and you have to be able to know how to overcome them when you just want to sit and talk about your problems.” She recounted stories of students speaking out in class and challenging her attempts to teach them. For example, one student said, “Why do you want to teach us this stuff. My mom did not go to school or college or anything, but we still have everything.” Based on these interactions, Alana perceived that some of her students felt they did not need an education because they had everything they needed at home, provided by parents who had little or no education. Alana spoke of students and their families having a negative view of education. In one-on-one interviews she highlighted that many of her student’s parents received government subsidies and had a low opinion of education.

Alana wished to advocate for her students but felt powerless to do so within her school structure. She felt a strong lack of support from her administration, who she described as not striving for quality education for all students. She identified concerns with students not attending classes and described her administrators approach to the problem. Her perception was that the school was “spoon feeding students” and just passing them through the system without supporting their learning. She used the example of having to pass students who did not attend classes. Despite attempts to discuss ways to support students, Alana felt dismissed by administrators, leaving her feeling powerless to advocate for the education she knew the students deserved. Alana condemned a system set up to “allow kids to have a poor education because on paper the administration can’t fail so many kids without repercussion from the state.” She

reported seeking support with attendance to which administrators told her that students were going through a lot and teachers should not be harsh on them.

At her school, Alana and her colleagues across disciplinary areas were required to structure lessons using a strict format. Administrators provided no leeway for teaching science, which Alana recognized "does not fit the exact same daily routine." Alana admitted making slight modifications to lessons when she felt she could, without her administrator knowing, but lacked the autonomy to make the shifts she felt were necessary to attend to equity. The inability to support students in ways that she believed would be most beneficial to students' success created a stressful work environment. Alana felt constrained by aspects of teaching that she felt she could not control.

Tom–Attending to Social-Emotional Needs

Tom requested support from the group with integrating social emotional learning (SEL) practices in his science classroom. He identified attention to SEL as a component of equity focused teaching because if focused on the total wellbeing of students. He described the challenge as a dichotomy between "hard sciences and social sciences" and he wished to learn how to attend to the social-emotional needs of students while also focusing on science content. Tom focused his problem of practice on an example lesson passive transport across a semipermeable membrane. The SEP was *Planning and Carrying Out Investigations*. He planned to teach the lesson to students at home during remote instruction. During his presentation, Tom spent time describing the science content and did not address the social or emotional aspects of his teaching. As a result, the initial feedback from the group focused on teaching the content to students during remote instruction. Eddie asked a question that bridged the content with the SEL approach that Tom was seeking, by saying "how do you introduce the topic to the kids." Tom

responded by describing himself a “story-based teacher.” He used his own experiences to engage students. For example, when introducing the concept of passive transport, Tom told students a story about catching a saltwater fish when he was child. Tom explained that he took the saltwater fish to his home and put it in a freshwater tank, where he had hoped he could keep it as a pet. Tom explained that he was surprised that the fish died. Tom shared that the story served as an engaging phenomenon and led the students on an adventure of trying to figure out why the fish died.

He explained that he invited students to share their ideas and valued their lives outside the classroom, stating that he frequently “goes off on a tangent” when a student has an interesting question. Group members helped Tom see that the act of valuing student’s lives and experiences was part of SEL. The discussion also led Tom and others to recognize that attending to students social-emotional health does not always have to be in the context of the subject matter content. Bryce stated, “I hope we don’t fall victim to thinking our content is dominant, that it is divorced from society, from student’s everyday context.” To explain the importance of understanding students’ everyday lives and experience when trying to make meaningful connections, Bryce shared how the experience of living in extreme poverty as a child afforded Bryce a perspective on the students’ lives that Bryce would not otherwise have had and articulated a view that community is an ideal connection between science and students’ lives. Petra added that by positioning students as scientists in the classroom, they begin to see themselves as having opportunities to engage with the content. She said, “how you frame the content can be a big part of SEL.” This rich discussion of the connection between content and the context in which students learn was important for Tom to reflect on SEL.

Tom's Noticing–Teaching is More Than Content. Tom's presentation was predicated on the idea that SEL and science teaching were separate topics that Tom did not know how to integrate. Through discussion he noticed that some of the practices he already used could be more intentionally and thoughtfully applied to reach his goal of supporting student's social emotional well-being. The group discussion did not address the full scope of instructional strategies suggested for SEL, such as specific actions for reducing risk factors and fostering positive adjustment to stressful situations. However, aspects of Tom's approach to teaching afforded him the ability to listen and respond to student's interests, questions, and connections. Tom noticed ways he connected with student's lives and became more intentional about positioning students as the explorers and investigators of their communities with their own stories to tell. He realized that the work he does to check in with students regularly, build their confidence as knowledgeable individuals, and frame their questions and wonderings as important, were strategies that created a healthy social environment. He also recognized that his teaching context differed from others in the group because he had complete trust of his supervisors and the autonomy to teach as he felt was best for his students.

Tom's Enactment–Focusing on Student's Mindset for Learning. Tom shared that he was struck by Bryce's comment about not having to always focus on content in the science classroom. In the post interview he shared that he was thinking a lot about "opening up a little bit more (to his students) to make sure that they are ready to learn and in the right mindset to engage with others in his class." Tom said,

> if kids come into my class not wanting to learn and I try to immediately start with content in the context of science class, then they are not going to get the science. But if I can

> create an even more positive culture and help them have a mindset that is ready for learning the content then they will probably get a lot more out of the class.

Tom explained that he has the trust of his administrators and the ability to be responsive to student's interests. He frequently gets off track with what he had planned for a lesson because a student has a question or wished to investigate a question that is related but often tangential to the lesson. Tom referred to these moments as "on topic tangents." Overall, Tom did not make significant shifts to his practice as a result of the community of practice discussion but gained confidence to deepen the attention he gave to student's ideas and interests. He recognized and valued the trust of his administration, stating "administration and the culture that you're teaching has a significant impact on the relationships that you can build with your kids." He noticed that when he asked students about their everyday connections to lessons, they participated more and were much more interested in the content. For example, when teaching the lesson on passive transport a second time, he asked students about how they cooked eggs at home and received a lot of varied responses. Tom shared that 65 of his 72 students had a unique answer and he noticed greater engagement in the lesson content. The small shift of centering student's lives and experiences, rather than only sharing his own experiences with the science led to a noticeable change in engagement and enthusiasm from most of his students.

Tom–Researcher Notes. Tom's experience was very different from others in the community. He described a high level of support from his administrators and the autonomy to teach in ways that he believed was most engaging to students. I noticed that Tom was very aware of his own sensemaking process. For example, he described his process of preparing to teach a new class, forensic science, which he asked his supervisors to allow him to teach because he felt it was "the STEM class of all STEM classes"–an ideal opportunity to integrate across content

areas. Tom explained that in preparation for teaching a lesson, he talked through the lesson out loud to himself in the car on the way to school, in his classroom when he was alone, and as he was engaged in everyday tasks. He rehearsed and considered how the lesson would go, explaining that "I need to hear what I'm saying for it to make sense." Tom also intentionally surrounded himself with people who he thought would make him better, stating "listening to people who are better than me at teaching will make me a better teacher."

It occurred to me as I listened to Tom describe his sensemaking process that his self-awareness and recognition of his needs as a learner was an excellent demonstration of social-emotional learning−the topic that he sought support with from the group. Creating an environment in the classroom where students had opportunities to express their own learning styles and needs emerged as the specific component of Tom's teaching craft that he wished to improve. When we discussed students' cultural assets as a component of learning, Tom shared that his classroom is "a cultural melting pot" and he does not recognize the influence of a student's culture on their individual learning. I noticed that the intersection of cultural ways of knowing, social-emotional learning, and sensemaking with science content became an area that Tom was interested in exploring as part of his work in this group and beyond. He was fortunate to have the support of his administrators and the autonomy to self-identify and address areas of professional growth. This aspect of Tom's work stood out in contrast to others in the group who experienced much more restrictive administrative oversight and school policy.

Penelope–Problem of Making Math Accessible

Penelope was a high school Chemistry teacher in a faith-based school that serves American and international students living in the United States. She presented her problem of practice by sharing her observation that a "significant number of students are challenged by math"

and she wished to make "quantitative chemistry more tangible for all her students." She addressed the SEP *Using Mathematics and Computational Thinking* and she focused on a chemistry lesson where students used stoichiometry to calculate the changes that took place in a decomposition reaction. Students calculated the change in density and conducted the experiment in the classroom lab (during remote learning Penelope recorded the lab). Penelope described that student's were able to progress through the mathematical steps of the lab activity but were not able to apply what they knew to explain the outcome of the experiment. She hoped to change the way she worked with students on the topic so that all students could be successful with the math and demonstrate understanding.

The group focused feedback on addressing commonly held deficit views of math. Bryce shared Bryce's experience with a school district removing Chemistry and Physics from the high school program of study. Bryce perceived this change as a response to administration adjusting the program of study because students did not demonstrate proficiency in the prerequisite course Algebra One. The group discussion centered around how to work against deficit thinking by using practices that make Chemistry more tangible and relatable to students. Ideas about making everyday connections to Chemistry emerged, including chemical reactions that take place when cooking. Pedagogical moves for making students thinking visible were discussed and experiences shared between group members. Some suggested using white boards as a tool for making math thinking visible. For example, Bryce shared the following insight:

> Struggling students need to visualize math and collaborate with math. (For example), I was tired of having my students tell me that they did the math…but I could not see it. I turned my desks into white boards and student were not allowed to do any stoichiometry unless they did it on the whiteboard, so I could see their thinking. Math is too often done

> in silence. We need to shift math to be a conversation. We need to stop doing math in isolation and make math discourse where mistakes are at the forefront of the learning process. I think you would have greater success with students being able to persist through mathematical challenges if you are able to make their thinking visible.

Participants shared examples of tools students can use to collaborate in the classroom and in remote instruction to talk about math while solving equations.

Penelope's Noticing–Practices that Make Thinking Visible. Penelope reported thinking deeply about the discussion, reasoning with the information she heard about how school districts close to her may have addressed student abilities in math and science. She explained that this information concerned her from an equity perspective and was inspired to investigate the practices of her school. She decided to take more of an active role in questioning common educational practices. Penelope noticed ways that she could shift her teaching to make students math thinking visible and applied her practical knowledge about the importance of understanding student ideas. Penelope reasoned that by including elicitation strategies, she would provide opportunities for students to bridge experiences at home with experiences in the classroom, so that both spaces were accessible for learning.

Penelope's Enactment−Eliciting Student's Ideas About Asthma. Penelope demonstrated the ability to translate and apply the suggestions made in the COP discussion to a lesson she was planning to teach the following week. She had moved on from stoichiometry and wished to make use of the suggestions in an upcoming lesson rather than adjust a previous topic at that time. She modified a lesson focused on interpretation of data to include elicitation of student's ideas about a topic that was meaningful to them in their local community, Asthma. By asking students in advance if they had experience with Asthma, she was able to glean their

interest in the topic. Penelope shared that she usually introduced the topic to students by telling them that there was a relationship between the number of trees in a given area and the incidence of Asthma. As a result of the community of practice discussion, she shifted the focus of the lesson to student's ideas and questions about Asthma. She asked them to analyze the data and determine if they believed there to be a connection. Penelope used a white board tool to elicit student initial ideas about asthma and the relationship between the number of trees in an area and the number of hospitalizations of asthma. Her anchoring questions were: What is asthma? What causes asthma? Is there be a relationship between the number of trees in an area and the severity of someone's asthma? (Figure 10). This small shift was intended to position students as knowledge creators. Penelope guided students in retrieving data from publicly available sources on tree cover and hospitalizations due to asthma. They proceeded to make connections and ask additional questions.

Penelope shared that her students were really interested in the topic because it had a "direct connection to an issue that they know about outside of school. Students have family members and friends with asthma, and they hear about it all the time." By asking students to identify their existing knowledge of the topic before jumping into the data collection, Penelope positioned the students experiences as valuable in the learning process. Applying this student-centered practice in a short period of time after the COP discussions demonstrated Penelope's competence and her scope of autonomy to make a change that was responsive to a perceived need in her classroom.

Figure 10

Penelope's Elicitation of Student's Ideas about Asthma

Note: Student names were removed from the comments. Each note was posted by a different student in the same remote class.

Penelope−Researcher Notes.

Penelope described a supportive teaching environment and perceived autonomy to make shifts to her teaching based on what she felt was necessary for her students. In addition to working with administrators, Penelope and her colleagues were collaborating to explore ways to "give students voice" in school activities and the classroom. They had already begun formal school wide professional development to explore issues of equity and diversity. As discussed earlier, Penelope was very aware of her position as a White female exploring race and diversity in society as well as in her classroom. During our conversations, specifically the one-on-one interviews, I found that my experience as a White female, who was also unpacking the impact of

racism in society and in my work as an educator, was very similar to Penelope's and we shared common thoughts about the role that we can play as advocates and allies for equity.

Penelope demonstrated strong content knowledge and thought deeply about how she could make Chemistry content tangible and relatable to student's lives. Her dedication to "the very hopeful process" of using "our voices to make change for what will be in the future" was evident in the time she took to read about racism in schools and society and her local work reviewing existing practices in her school. Through conversations with Penelope, it became clear that her participation in this study was part of her ongoing journey exploring equity as an educator and as a White female interested in advocating for social justice.

David–Teaching Chemistry Remotely

David's motto for his classroom was "experience the science to learn the science." He shared this approach in his presentation which focused on methods of teaching chemistry remotely, something he was feeling very anxious about. David focused most of his presentation on describing school demographics and the apparent socioeconomic disparities between students. He shared that most of his district was lower middle class working families with a small fraction of upper middle-class families. He made a point to state that "they all know whose parents are who." David deviated from the tuning protocol initially by not directly stating his connection to equity. However, when prompted to focus the discussion on attention to equity, David responded by stating that there was a huge financial disparity in the district, and he had some students who reported not being able to access simple materials like tape and pencils. He was concerned with being able to teach chemistry while students were learning remotely because of access to materials. The group feedback initially focused on methods of distributing materials during remote teaching. However, a pivotal moment occurred for David when Tom suggested that there

are amazing connections to chemistry in the home through activities students do regularly, such as cooking:

> Tom: Introduction to chemistry is related to cooking. You can talk about something as simple as making an egg meringue…with egg whites, which are proteins, and you can talk about how the chemical and physical properties change when you incorporate air and you get these stiff peaks and what's causing this to happen. You can incorporate baking and all that stuff too. And it's, it's something that kids can do with families.
>
> Bryce: I completely agree, Tom. At Thanksgiving, I used an idea from our group sessions and invited my students to my virtual Thanksgiving table. I asked them to each bring something from their culture to the table. Students brought traditional African foods, Dominican foods such as Mangu. We compared Mangu and talked about chemistry through their foods…heterogenous and homogenous mixtures…. the Maillard reaction, which is used to brown food, give flavor, and crispness.
>
> Penelope: I would add burning also and then you have a segue into talking about carbon dioxide.
>
> Tom: Another thing with cooking…you can play with acids and bases with reduction reactions.
>
> Carisa: I would also use cabbage and cabbage juice…beet juice. The kids really respond to color changes.

The group dialogue supported David's noticing of connections between chemistry and students' everyday lives, specifically while learning at home during remote instruction. Notably, the language used by individuals in the discussion thread above positioned students, their homes, families, and foods as assets for learning about chemistry. This asset-based language was not

always present in other group discussions and was a notable feature of the positive feedback provided during David's presentation.

David's Noticing–Shifting the Focus to Students' Culture. David shifted his focus from the socioeconomic disparities between students, which he saw as a barrier to teaching students when they were at home with limited resources, to focusing on the common practice of cooking and the content connections between cooking and chemistry. He enthusiastically explained how centering students' cultural experiences with cooking directly aligned with his experiential approach. The community of practice discussion helped him look beyond the classroom and identify connections to chemistry that valued students' experiences in their unique contexts. He noticed students and their homes and families as assets for learning. The group helped him renegotiate deficit perceptions of access to learning opportunities in students' homes and families to think of ways that students' lives could be valued as part of the chemistry curriculum and apply that new knowledge to his upcoming unit on chemistry.

David's Enacting–Valuing Student Culture Through Kitchen Chemistry. David thought deeply about the conversations that took place in the COP and explored the resources that were shared. In the post-interview he spoke specifically of Bryce's lesson where student's cultural experiences brewing coffee with their families was valued as a content connection. David reports "thinking about that example all the time now when planning." He was quickly able to apply this approach by inviting students to share their experiences at home in a lesson on mixtures and solutions. David described moving his remote classroom to his kitchen where he cooked "egg sushi" in front of the camera and discussed the content connections. Egg sushi is a recipe David and his family make in their home. It involves scrambling eggs in a pan and rolling

vegetables in the cooked egg, making a sushi-like, bite-sized roll – what David referred to as a heterogenous mixture.

In addition to David's cooking example, each student was given the option of choosing an example from their own kitchen that demonstrated mixtures and solutions. They were not required to cook anything, but some students did. David reported, "students chose heterogeneous mixtures like cereals, a homogeneous mixture of lemonade...another student was baking with her mom." David asked students questions and they responded in the chat and on camera. He enthusiastically shared, "there were more students with their cameras on, engaged in the lesson than I had all semester."

David reported keeping a screen shot of Bryce's coffee filtration lesson example and a periodic table of Black History Month taped to his computer screen to remind him to incorporate these new ideas into his planning and teaching. Learning about the filtration lesson was a significant point of clarification for David because it demonstrated how to use students' cultural experiences as an entry point to talking about science content. David was eager to try new ideas and "reimagine" his teaching after this experience. David recognizes that the other science teachers with whom he works may not be amenable to change but looks forward to having success with his students so that others will decide to shift with him, either because they see student success or because students start requesting to be in his class–an occurrence that has been a motivator for his colleagues in the past.

David–Researcher Notes. My observations of David were that he was very dedicated to creating exciting learning opportunities for his students and always went above and beyond to be an excellent educator and colleague. He confided that he originally joined the study to build his "teacher toolbox" and learn from others. However, he contributed just as much as he learned. There are two aspects of David's work that resonated most with me. First, David represented his role with his colleagues as the teacher who tried out a new idea first, only to be joined by his colleagues when David had success. David described this leadership role with pride. As I listened to David describe how hard he worked, I could not help but wonder if he was being taken advantage of by his colleagues. David also had a positive relationship with his administrators who encouraged him to work toward student directed learning. He reported a recent conversation with his administrator where he shared his "egg sushi" lesson. David was told by his administrators that if he was to make the shift to beginning the lesson by having his students ask the questions about solutions and mixtures, the lesson would have been "level four", the highest level on the Danielson Framework (Danielson, 2013), which was used for school wide teacher evaluations. He shared that the conversation with his administrator resulted in David thinking even more deeply about how to engage the students in asking questions that drive learning.

The second component of David's description of his position at his school that resonated with me was his awareness of his race. As the only Black teacher in his building, David described himself as a "tall, Black male who stood out" in his context. He recognized that when he walked into the auditorium full of students, he was noticed. David shared, "When I first started in 2005 (the school) was 60% Caucasian 40% black with a small percentage in there of other. Now it's kind of reverse. It's 60% African American, 35% Caucasian, and maybe like 5%

other." Thinking about his experience as a student and a teacher with regard to race, David shared

> My students, some of them, are surprised to find out that the neighborhood that I grew up in was mostly White. I have had to put myself into the school community when I speak to students. My block 1 class is very different than my block 3 class. They view me as the sports person−basketball, football, rap music−all the very stereotypical African American male things. It's all true.

David was keenly aware that students engaged him in conversation about popular culture, sports, and current events in very different ways than they did with his older White male colleagues. During our conversations I sensed that David felt burdened by the current attention to racism across the country. When describing his belief that "students should not feel constrained by their gender, or their ability level," David added "more recently, there are new challenges of equity that I'm not even sure I know how to address… so I try to keep it all science." David's interest in teaching science and not having to carry the burden of talking to students about racism in light of recent national attention to racism was an important component of our one-on-one discussions; however, he did not raise them in the community of practice. I continued to reflect on this part of David's experience as an educator and recognized how David's experience pushed me to think about race and classroom teaching more deeply.

Bryce–Problem of Engaging Students in Activism

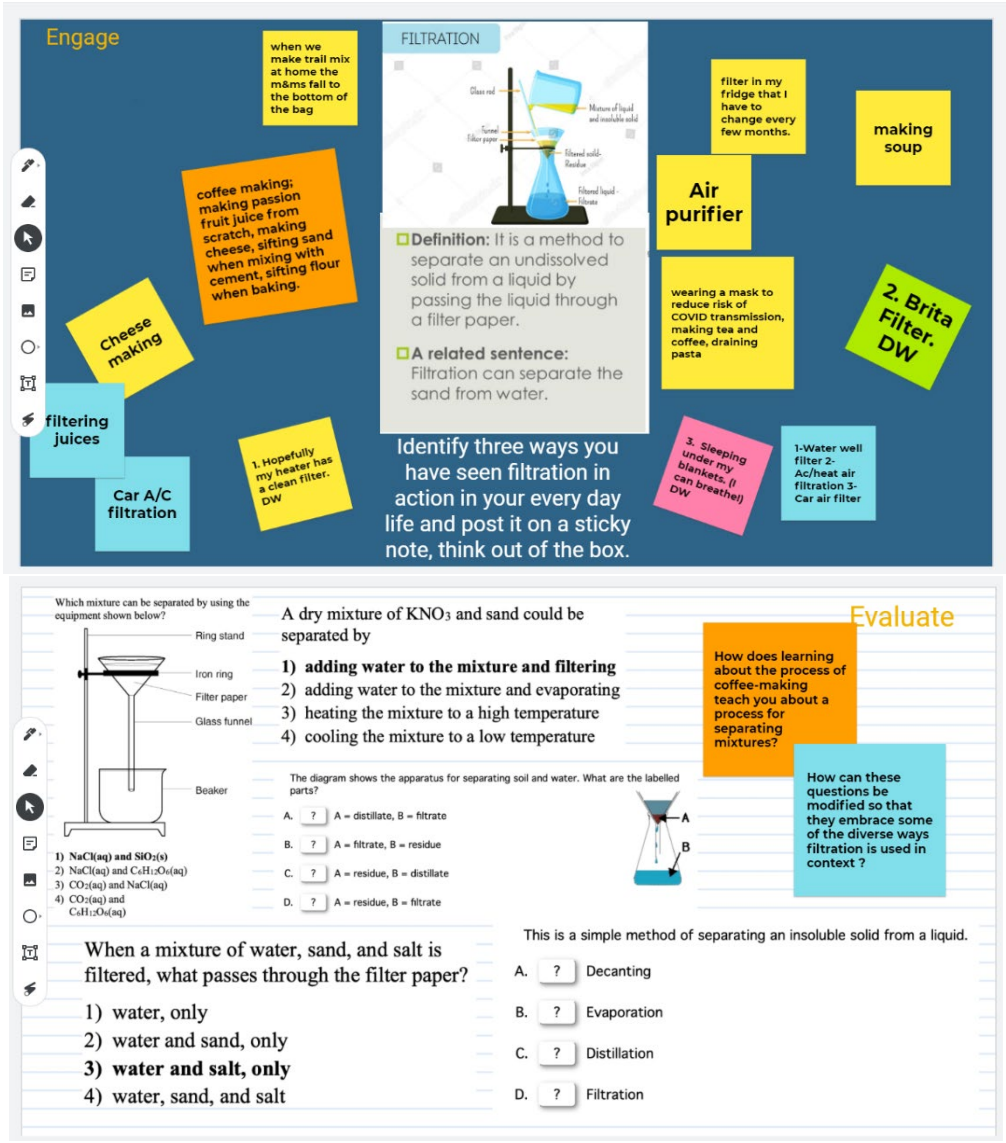
Bryce shared a lesson focused on the Chemistry concept of mixtures and used filtration as a tool to demonstrate separation of substances from mixtures. He believed the lesson did a good job of valuing students' cultural connections. Bryce asked high school students to describe ways that they made coffee at home and shared that when he implemented the lesson, students enjoyed

talking about their families varied methods for brewing coffee. Bryce used a whiteboard tool and modeled his lesson in the 5E lesson plan format with the group (Bybee et al., 2006). During the Engage segment of the lesson he asked students to "identify three ways you have seen filtration in action in your everyday life and post it on a sticky note. Think out of the box" (Figure 11). Bryce briefly described the Explore and Explain segments of the lesson where students learn about coffee drinks, mixtures and solutions from various cultural perspectives. Examples included Scandinavian Egg Coffee, Brazilian Cafezinho, and Malaysian Kopi. Each coffee types served as an example of using filtration. In the Elaborate, students apply their knowledge to design a filtration device at home with materials that they have available.

After introducing the lesson, Bryce asked the group to support Bryce in thinking about ways to engage students in activism in their local community as a way to apply their knowledge of filtration. The problem of practice Bryce presented was "how do I get my students to engage in activism that supports change for them and for their communities?" Bryce hoped students would synthesize knowledge of substances and mixtures, and engineering design, in a final project that engaged students with local environmental concerns. Responses from the group included a variety of resources for accessing local environmental groups, urban advocacy groups, and politicians.

Figure 11

Bryce's Elicitation Activity (top) and Connection to State Assessment Questions (bottom)



Tom: I suggest you consider looking into fair trade coffee as a sustainable practice. It is so much different than commercialized mass-produced coffee...you can incorporate some possible culture in there, too. I mean you have a plethora of culture with coffee production.

Penelope: It sounds like you are specifically interested in your students knowing about clean air and clean water…when you live in certain neighborhoods more people drive

older cars and the emissions from older cars impact air quality more than new cars. I think to become an activist, you have to be able to gather data. I would look for opportunities for students to collect real data about the water in their community and then use that to encourage activism.

Carisa: I had a parent come to school one year from the State Soil Conservation District and she talked to the kids about how the water drains in the city. She explained that when there is a flood the rainwater cannot drain properly–the way city stormwater was designed - and all the waters get mixed up. The river gets a lot of trash, and it also gets a lot of sewage water. Environmental conservation organizations can come to your classroom and help you design something that is appropriate for kids based on what kind of problems are happening around their neighborhoods.

Penelope: When we work on this topic, I always use the Flint Michigan water crisis because the story shows that citizens were involved in bringing the problem to the attention of the authorities…Students can use their voices to bring issues to the attention of authorities.

In addition to these and other suggestions about activism projects that were based on local issues and engaged local assets, participants shared ways to allow students to communicate their ideas. David suggested allowing students to choose how they share their information through popular social media platforms that may inspire them to make connections between content and their everyday lives. Members of the group encouraged Bryce to use social media that students enjoy using, such as popular the video platforms TikTok and YouTube, to allow students to communicate advocacy messages through platforms that are central to youth culture.

Participants shared a wide variety of resources and ideas for advocacy, demonstrating the breadth of knowledge across members of the group for engaging students in science.

Bryce's Noticing−Opportunities for Advocacy. Bryce's filtration lesson served as an exemplar for the COP and was repeatedly referred as a model of how to connect content to students lives and culture. Bryce worked in the same school district as Alana and Eddie and followed the *Pursue STEM* curriculum. Bryce autonomously decided how to teach the curriculum based on his perception of what his students needed and the practices that aligned to his sense of purpose as a teacher. Bryce's focus on opportunities to engage his students in local advocacy activities related to science and math content, was an example of the critical approach Bryce took to teaching. In addition, Bryce recognized the importance of collaboration in becoming a better educator and enthusiastically engaged in dialogue with other members of the group.

Bryce's Enacting–Embracing Local Activism. Bryce applied an activist focus to design a lesson following the community of practice presentation. Inspired by a commercial on local television about a new process for voting for local government officials, called rank-choice voting, Bryce designed a lesson that integrated math concepts and the community issue of voting. The city where Bryce taught recently announced that they were changing their voting system to ranked-choice voting, a process that allows people to vote for multiple candidates, in order of their preference. Voters select their first, second, third choice (or more as needed) for each position and the candidate with the majority (more than 50%) of first-choice votes wins. The commercial that Bryce saw on television indicated that most residents in the area did not know how rank choice voting worked. The information inspired an emotional reaction for Bryce, who said "it's just so interesting to me that right in the middle of this transition, where Black and

Brown people are gaining positions of leadership, they introduced a whole new voting system." Bryce recognized that students and their families knew little of nothing about the new system. Inspired by the opportunity to be an advocate for his students and their families, Bryce designed a lesson where students would learn about the local candidates and learn math concepts related to election results. They would apply their knowledge of mean, median, mode, and range. Bryce planned to support students with graphing the data and following the election results to determine the outcomes mathematically. For Bryce there was a clear opportunity to take a social, political issue and make it a teachable moment. The passion for what Bryce recognized as a social justice issue in the community led to a lesson that guided students to apply math concepts to an authentic, real-life situation embedded in the local community.

Bryce–Researcher Notes. Similar to all the participants in this study, Bryce demonstrated a sincere dedication to Bryce's students. However, unlike others, Bryce shared an authentic connection to student's experiences with poverty, racism, marginalization, and social injustice, which inspired Bryce's teaching practice. I recognized that Bryce worked in the same school district as Alana and Carisa and was required to follow the same curriculum. Yet Bryce described making decisions to teach students in ways that Bryce felt was best, despite administrative oversight. I observed that the passion and dedication that Bryce brought to teaching was so strong that the threat of disciplinary letters in his professional file did not deter Bryce from teaching with a social justice stance. Other members of the community seemed in awe of Bryce's confidence and ambition to push against school policies that Bryce did not agree with or recognize as positive for students.

As the facilitator, I recognized Bryce's contribution to the group discussions and the strong influence Bryce had by modeling ways to connect classroom content to important social

justice concerns in the local community. As I reflected on Bryce's position in the group I wondered, "what if there was no Bryce in this group?" I questioned whether the group would have responded with the same interest if I had shared the example Bryce had shared, or if Bryce's position as a classroom educator and peer made the example more authentic and influential. Throughout our work I recognized Bryce's unique position as a classroom educator and an advocate for social justice. Bryce was doing the work of critical education, sometimes on the fly, as issues in the community inspired a response in the classroom. I wondered how we teach educators to have a strong grounding in issue of equity if they have not experienced inequities the way Bryce had.

Summary of Problem of Practice Presentations

Each of the seven participants discussed above selected a problem of practice that they identified in their individual teaching context to bring to the group for discussion. As a result, the group discussed many facets of equity-focused work and learned from preparing and sharing their own problems of practice, as well as participating in structured feedback for others. The snippets of dialogue and occurrences of noticing that lead to reasoning with new ideas demonstrated how the practice of structured discussion provided opportunities for participants to make sense of new ideas.

Carisa noticed the way she started her lessons and became aware of the lack of representation in lessons. She noticed Bryce's use of the term "Eurocentric teaching practices" and wished to know more. Eddie noticed inconsistencies between his administrators approach to teaching ELLs and what he felt was best for his students. Alana noticed restrictions in her teaching context and became aware that teachers can be advocates for themselves and their students. Tom noticed opportunities for attending to equity beyond teaching science content.

Penelope noticed opportunities to center her student ideas through elicitation strategies and focus on community issues. David noticed opportunities to center culture and value students' lives at home. Bryce noticed opportunities for students to engage in local advocacy. Each of these occurrences led to opportunities for participants to question what to do next, a central component of the active and generative process of sensemaking for equity. They did this reflective work by listening, reflecting, pushing each other's thinking, getting uncomfortable at times, and creating knowledge through critical dialogue (Kohli et al., 2015).

Some participants were able to make immediate shifts to their practice. For example, Penelope, David, Tom, and Bryce reasoned with the suggestions they received and made decisions to enact shifts to their teaching based on their professional knowledge. Alana and Eddie demonstrated progress in thinking about what equity means and looks like in the classroom, however, they felt constrained to enact changes because of their teaching context. The way in which each participant negotiated their understanding of equity practice and made decisions about what to do with that information exemplifies their individual sensemaking processes within the collaborative group during the time frame of the study. Each participant started the work from a different point with their thinking about equity and progressed in varied ways throughout the study (Ball, 2012). In the next section, I address productive tensions that emerged through the community of practice dialogue in response to the three main research questions of the study and draw on literature in the field of science education to make sense of the findings.

Chapter Six: Discussion

This chapter is about making sense of the work participants engaged in during the community of practice. I organize the discussion of the findings by addressing the three research questions using evidence of sensemaking that occurred throughout the community of practice. I draw upon the principles of the design discussed in Chapter One and the body of literature that supports professional learning for NGSS SEP's and equity, presented in Chapter Two. Throughout the discussion I address productive tensions that emerged in the findings as participants made sense of what equity meant to them and to their teaching practice.

Looking across tuning protocol presentations and the resulting discussions, there were five productive tensions that emerged as important sources of ambiguity that led to sensemaking about equity practices. First, the group noticed many different definitions of equity and contextual ways of thinking about how equity should be addressed in teaching. Second, participants recognized that inclusion of students involves centering their ideas in learning opportunities. Third, participants noticed their use of language about students and became mindful of deficit language. The fourth productive tension that emerged was teachers' scope of autonomy for affecting change. Fifth, teachers noticed that equity pedagogy includes valuing students' multilingual skills as assets, rather than deficits. I address the first three tensions in response to research question one because they contribute to understanding how teachers focused on equity. I address the fourth and fifth tensions in response to research question two, as they help identify contextual support and barriers to translating ideas into practice.

To begin, I address research question one: *How do teachers make sense of equity through negotiations with peers in a professional community of practice?* Participants engaged in sensemaking about equity and teaching the SEPs by committing to the work, selecting

consequential problems of practice, and providing each other with thoughtful feedback. Understanding how participants negotiated ideas about equity requires considering the components of the professional learning model. Therefore, in response to research question one I discuss the design and implementation of the model.

The second important component of how teachers engaged in sensemaking involves the teachers themselves and the tensions they noticed throughout their dialogue. I discuss the various ideas that teachers held about equity in practice and address the common perspective of equity as inclusion from a teacher-focused perspective. In addition, the use of asset and deficit language about students emerged as a productive tension for understanding participants sense of purpose for equity and their recognition of systemic practices that they can address in their own teaching.

Next, I address research question two, *how do participants translate their ideas about equity in planning for enactment*. Sensemaking involves deciding what to do with new knowledge. Translation of the new practice into teaching includes knowledge or competency with equity practices. Findings suggest that the construct of teacher agency was an important indicator of enactment. The scope of autonomy, or power to make a difference, had an influence on teacher's ability to enact new practices in their specific contexts. Administrators influenced some participants' scope of autonomy, in both encouraging and restrictive ways, suggesting that administrative oversight is an important factor for enacting equity pedagogy. I discuss specific examples of Eddie and Alana's perceived scope of autonomy for making changes to curriculum to demonstrate the importance of context for attending to equity.

The third research question addresses the relationship between the SEPs and equity. I asked, "*to what extent are science and engineering practices and equity related components of teachers' practice?"* Findings suggest that teachers who were intentional about centering

students' and their ideas and recognized the purpose of equity-focused practices were able to select and implement high-leverage practices intended to center students in the SEPs. Equity and the SEPs can be addressed independent of one another. Teaching with a focus on both requires purposeful attention to students and the practices that center their ideas. Findings suggest that teachers can decide to implement high-leverage practices as pedagogical tools for attending to students (Calabrese Barton et al., 2020). Response to the third research question both supported deeper understanding of the interconnection between equity and the SEPs and led to questions for further inquiry with respect to current efforts to advance high-leverage practices. The productive tensions that emerged in this study contributed to understanding of teacher's sensemaking about equity and raised additional questions and opportunities for research, as can be expected in generative critical work (Brito & Ball, 2020).

Research Question One−Making Sense of Equity

In the following pages, I address research question one: *How do teachers make sense of equity through negotiations with peers in a professional community of practice?* by discussing the design of the professional learning opportunity and the productive tensions that emerged when participants engaged in dialogue about equity.

The Professional Learning Model

Using a design-based research model, I drew upon literature in the field to carefully consider research-based practices for professional learning when designing and implementing a community of practice with ten teachers. The participants in this study and my position as facilitator of the community are both important factors to consider. Participants volunteered to participate in this work, expressing an interest in the topics of the NGSS SEPs and equity. They all had previous experience with an online community of practice through the GenerationSTEM

program. This is significant because teachers are often overwhelmed with the vast number of conflicting demands placed on them, especially during times of reform (Penuel et al., 2007). The previous relationship with the community and with me as the facilitator, contributed to participants trust that engagement in the work was worthy of their time and effort.

Furthermore, as a teacher educator recognizing the "three-story challenge" of my position I carefully considered the research that informed the work, drew upon my professional knowledge of teacher learning, and positioned myself as one professional among ten other equal professionals (Hawley & Valli, 1999; Windschitl & Stroupe, 2017; Zeichner et al., 2015). I was continually reflective of my role in the community and the ways that I was responsive to participants needs as a member of the group. This approach is markedly different from common practices in professional development (Banilower et al., 2018; Darling-Hammond, 1997; Darling-Hammond et al., 2017). Four primary principles informed the design of the professional learning opportunity. First, I considered research-based practices in teacher learning. For example, teachers need time to make sense of new ideas (Darling-Hammond, 1997; Supovitz & Turner, 2000) and benefit from collaborative opportunities to unpack meaning for their teaching practice (Antink-Meyer & Arias, 2020). Knowledge of teacher learning through collaborative communities of practice informed the design of this community of practice (Wenger-Trayner & Wenger-Trayner, 2015; Wenger, 2010). The participants engaged in dialogue and collaborative work over a 16-week period with ten online meetings. As shared in the findings in Chapter Four, they engaged in discussion focused on the presenter's problem of practice. Participants respectfully challenged one another to think about their practice in different ways with respect to equity. For example, Carisa and Eddie approached teaching English Language Learners in very different ways. They demonstrated the ability to engage in critical discussion and reflection to

rethink practices in support of their students (Liu & Ball, 2019). Like Nagle and Pecore (2019) who also focused their research on deepening teacher understanding of the SEPs, the participants in this study were able to develop authentic connections between the SEPs and student experiences because the structure of the collaborative space was not "contrived or forced into classroom instruction" (p.8).

I encouraged participants to think about centering students in their work as equity practice by modeling collaborative, equity-pedagogy that considered all participants in the group. By situating the work in a strong theoretical background on how teachers learn and using examples from classroom practice that put student ideas at the center of planning and enactment (e.g. Larkin, 2019; Windschitl et al., 2018), I modeled equity-pedagogy and shared successes in a variety of contexts (Hayes et al., 2019). I also made sure to highlight the ideas and examples of participants who modeled equity pedagogy in their teaching as exemplars. Finally, I grounded the design of the community in the notion that teachers' actions are transformative, and they can be agents of change. The community was designed to allow teachers to engage in the generative work of making sense of ideas about equity–to notice something new, to reflect on their practice and grapple with inconsistencies between what was new and what they held as existing conceptions, and to decide what to do about it. As Liu and Ball (2019) state, generativity is the "generation of new or novel behavior in problem solving" (p. 93). Participants were able to make small shifts to their teaching, either through planning or planning and enactment, with the intention of addressing the problem of improving their equity practice. The design of the professional learning experience was consequential for participants' sensemaking.

Tuning Protocol−Teaching with Attention to Equity. The practice of using a structured protocol for discussion in this community of practice served as an organizational tool and as a

model of equity pedagogy. Each participant had time to select, prepare, present, and receive feedback on a problem of practice that they selected, given two guidelines. I asked that problems of practice focus on teaching the SEPs and that they be connected to an issue of equity. I did not dictate what issues of equity were but rather allowed definitions of equity to emerge through data collection. They varied within the group. By allowing participants to select a problem of practice I attempted to focus on the meaningful decisions that teachers make and what they do as professional teachers (Ball & Forzani, 2009). The structure of the protocol allowed all participants to share equally and dedicated equivalent time to working on each participants' idea. In Chapter Four, I described Eddie's initial concern with using the protocol and his final reflection after having participated in the community. His growing level of comfort with the protocol over time is an example of how well the tool functioned for framing the process of presenting, responding to clarifying questions, and then listening to others "incubate" ideas in response to the presentation. The protocol provided a structured and safe space where all voices were valued (Settlage & Johnston, 2014).

Productive Tension−Defining Equity Can be Context Specific

The process of making sense of equity and thinking about equity pedagogy required participants to consider what equity meant to each of them individually and be able to engage in discussion about equity throughout the study. Their ideas were grounded in their experiences and professional knowledge. David, Penelope, and Carisa focused on developing positive relationships with students through supportive and caring actions as teachers. They recognized efforts to maintain respectful relationships with students as equity practice and articulated the various ways that they actively foster positive relationships by sharing stories of their interactions with students. Penelope also discussed efforts to advocate for students and to support

them in finding role models within the school community. Bryce shared the ways that Bryce connected with student's everyday lives through content and open dialogue about social and political issues that were central to students lives. Alana focused on issues of access to resources and the value of education in the community. Tom described equity as a process of learning about students and their needs and then supporting them, as necessary.

The diverse ideas that participants held about equity and what equity practice looked like in the classroom supports findings in the literature that suggests that equity is broadly defined and poorly understood in practice (Windschitl & Calabrese Barton, 2016). As participants shared in survey data and post interviews discussions, their understanding of the complexity of equity grew and they were able to think about issues of equity from the perspective of macro level social concerns and micro level contextual issues in their classrooms (Ladson-Billings, 1995). Participants ideas about equity align with Windschitl and Calabrese Barton (2016) description of equity, which is well grounded in literature. The authors define equity in classroom instruction as "providing opportunities for all students to learn challenging ideas, to participate in the characteristic activities of the discipline, and to be valued as important and fully human members of the science learning community" (p. 1101). The findings of this study suggest that attention to equity is contextual. Participants benefitted from listening to and working on problems of practice where they each noticed a different component of their practice with respect to equity.

Productive Tension−Inclusion Requires Focus on Students' Ideas

Upon beginning this work, each participant described their role as facilitator and talked about their teaching practice through the lens of inclusion. They shared individual ways that they tried to engage all students and provided support for each individual learner. Teachers talked about including students and making important connections to their lives, however, most

described an approach to teaching that was centered on their ideas as the teacher, not their students' ideas. They relied on model curriculum and their own carefully selected phenomena, claims, or assumptions about students' experiences to engage students in lessons. For example, as described in Chapter Four, Tom used stories from his own childhood to engage students and David relied on scenarios, such as NASA personnel calling to invite students to be part of a mission. Overall, participants felt responsible for making connections available for their students.

As the community of practice work progressed, participants recognized that attending to equity was more than including students in learning opportunities that were defined by the teacher. For example, David recognized students' experiences with cooking as cultural assets that had meaningful connections to chemistry content. Using Bryce's lesson on coffee filtration as a model, David noticed the value of centering students' culture. Bryce's examples of teaching became exemplars of equity practice for the rest of the group and were frequently revisited in conversation, a finding that supports literature suggesting that models of practice shared by colleagues are often most influential (Garet et al., 2001; Guzey et al., 2014).

Relying solely on teacher defined connections limits the ability for students to connect their values and experiences outside the classroom. When teachers take sole responsibility for making connections to content, they may miss the opportunity to situate learning in contexts that are familiar or meaningful to students. Participants process of noticing that attending to equity was more than including students in learning opportunities that were defined by the teacher, became an important productive tension and opportunity for improvement (Calabrese Barton & Tan, 2020; Calabrese Barton et al., 2020). They began to recognize students and their families as cultural beings, with experiences and ways of knowing that contributed richly to understanding content and engaging in the SEPs. Rather than trying to make connections for the students,

participants demonstrated progress with planning and enacting practices that gave students voice and made space for them to share cultural connections to content and practices.

Productive Tension−Language Use About Students

I recognized participants use of language about students as a productive tension that led to participants noticing, questioning, and deciding how to proceed. This active process of sensemaking about how students are positioned in everyday language influenced all members of the group. As each participant spoke about their students and their teaching, the other members of the group listened and noticed their use of language. Some participants used language to describe students, communities, and teaching contexts that was misaligned with their self-described ideas about equity and their ability to be inclusive of all students. This deficit language was inconsistent with participants' supportive and encouraging ideas about their students. In addition, occurrences when individuals used affirming language were noticeably different from deficit language. Language use became a productive tension that led to participants becoming aware of how they talked about their students.

This tension is important to explore as it leads to the question of whether teachers can engage in equity-based teaching practices when they use deficit language about students. Research indicates that teachers can articulate an inclusive and equitable vision for teaching yet use language that is contrary to that approach (Garcia & Guerra, 2004). As findings suggests, teachers may not recognize that they have a deficit approach, or they may use deficit language because they are immersed in a system that endorses a deficit view of historically marginalized students. They may learn to speak about students using categorical terms but do not consider the implications of their language use (Carlone & Johnson, 2012; Geneva Gay, 2010a; Johnson, 2011; Ladson-Billings, 1999).

Specific occurrences of language use stood out as discussed in Chapters Four and Five. The ways in which participants described their roles as facilitators of learning revealed that some thought of themselves as responsible for exposing students to experiences to which they would not otherwise have access. Kathryn's use of language at the beginning of the study suggested her unrecognized bias towards students who she also cared deeply about and worked hard to support. Through listening to others and reflecting on her own use of language, Kathryn became aware of her language use and began to explore both the implications for her students and specific adjustment she could make to the way she spoke about students.

Similarly, Alana also spoke of students and their families perceived negative view of education. She shared a deficit view of families on government subsidies and recounted numerous conversations with students who shared negative ideas about school. An overgeneralization about family background and the low value placed on education in immigrant families is documented in the literature (Lareau, 1987). Garcia and Guerra (2004) explain that educators "believe that the students and the families are at fault because, from their perspective, "these children" enter school without the necessary prerequisite knowledge and skills and that so-called uncaring parents neither value nor support their child's education" (p. 151). Alana articulated dedication to supporting students but grappled with how to do so when she felt she did not have the support she needed in the classroom. She maintained a deficit approach towards her students, families, and the school which she perceived did not provide the support students needed.

Carisa shared similar concerns for students, many who recently arrived in her school from other countries and did not know the English language. However, she expressed frustration with the lack of support available to students within the education system, not with the students

themselves. Despite articulating an affirming view of students and their language assets, Carisa used deficit language to talk about her students, saying that her ELL students have "speech and language deficits" and have "low" reading levels.

Kathryn, Alana, and Carisa's use of deficit language to talk about students did not align to their stated ideas about equity and inclusion of students in the classroom. Carisa also used terms to describe students that were inconsistent with the way she described their language abilities. Garcia and Guerra (2004) suggest that individuals can be "well-intentioned, caring individuals but are unaware of the deeper, hidden, or invisible dimensions of culture" (p. 154). The examples shared in this study align with commonly recognized uses of language that perpetuate biases about language, culture, race, communities, and families (Hudley & Mallinson, 2017; Lodge, 2017). Engaging in the community of practice discussions provided all participants an opportunity to listen to others language use and consider their own. Moments when participants used asset language became "light bulb moments." For example, Bryce used the term "language enhanced" when asking Carisa about her students. This was a noticeable occurrence that that led to individuals become aware of their own language use. This tension between deficit language use and otherwise affirming views of students raises the question of whether teachers can enact equity practices when they use deficit language about their students.

The findings from this study suggest that listening to others and becoming aware of language use is an important part of attending to equity and recognizing systemic barriers to equity. A more complete understanding of the connection between teacher's use of language and their ability to support their students with equity practices is an opportunity for future research. Awareness of language serves as an example of how participants made sense of new ideas in the

community. The community of practice provided designated time and a safe space for listening to others, which allowed the group to explore specific aspects of equity.

Research Question Two−Autonomy to Enact Equity

In response to the question of *how participants translate their ideas about equity in planning for enactment*, the construct of teacher agency was important. The findings suggest enactment of equity practices is related to participants competency to enact new practices and scope of autonomy within their context. Some participants were able to enact changes to their teaching promptly, while others cited restrictive administrative oversight. To make sense of this question I discuss participants behavior as autonomous professionals in the community of practice and in their teaching contexts where negotiation of school-based expectations emerged as a productive tension.

Productive Tension−Teachers as Agents of Change

The ten participants in this study demonstrated autonomy as professional teachers by volunteering to take up the work involved in engaging in this community of practice. It is consequential that they took it upon themselves, independent of their teaching responsibilities, to improve their practice and collaborate with others. As Pantić (2017) notes, teachers with agency demonstrate a sense of purpose, the belief that a certain practice is worthwhile. Throughout the work, participants shared their individual identities and experiences with one another, demonstrating the "human-centered" and "emotional" work of teaching (Eteläpelto et al., 2013) and providing a context for framing the problems of practice that they brought to the group for discussion (Hammerness et al., 2005). They shared stories and provided context for thinking about equity across contexts and centering students in their teaching. Those who were able to enact or plan to enact shifts to their teaching based on their work in the community,

demonstrated competence, or knowledge of how to enact practices to attend to equity in their teaching (Pantić, 2017). As Kennedy (2016) contends, "enacting a new idea is not a matter of simple adoption but rather a matter of figuring out whether, when, and how to incorporate that new idea into an ongoing system of practice which is already satisfactory" (p. 11). The findings suggest that all teachers recognized equity as meaningful to science teaching, however, some were able to enact shifts to their planning and teaching during the study while others were not (Berland et al., 2016). As Biesta et al. (2015) state, the decisions that teachers make are influenced by social, professional, personal, and context specific dynamics that influence how individuals shape their responses to problematic situations. While all participants demonstrated purpose for engaging in the work of improving teaching with an equity focus, the participants who had autonomy, either because they felt supported in their teaching context or because they made decisions regardless of administrative oversight, were able to enact practices in their contexts.

Penelope, David, and Tom expressed having autonomy to be responsive to students in their classrooms and make decisions about how to approach curriculum. Carisa, Eddie, and Bryce explained their willingness to be autonomous when they felt it was necessary for the benefit of their students and made shifts to district mandated curriculum when needed. Alana was unable to shift practices in response to her students' needs due to strict administrative oversight. The varying levels of autonomy within each context emerged as a productive tension for teacher's perceived ability to enact equity-focused practices.

Alana felt strongly that she wished to advocate for her students but felt powerless to do so within her school structure. Her goals as an educator were unsupported by her administration, who she described as not striving for quality education for all students. Alana believed that

students should be getting the support they need, especially during difficult times, like the shift to remote learning, and that they should be held accountable for hard work. Alana admitted making slight modifications to lessons when she felt she could, without her administrator knowing, but lacked the autonomy to make the shifts she felt were necessary to attend to equity.

Bryce, worked in the same school district as Alana and was required to follow the same curriculum. Bryce described making decisions to teach students as Bryce felt was best, despite administrative oversight. Bryce's strong equity stance was the underlying motivation for decisions Bryce made, a characteristic that was noticeably different from other participants in the study. Bryce made autonomous decisions regardless of administrative support.

Participants who reported autonomy to make choices about how to teach students took a very different approach to equity than those who felt constrained by their curriculum and their administrators' oversight. Tom reported complete autonomy and shared multiple occasions of exploring ideas that students wanted to explore, completely deviating from his original plan because he had the freedom to be responsive to student's inquiries. This was an aspect of his teaching context that he valued greatly and recognized was quite different from other participants in the group. David described a positive relationship with his administrators who encouraged him to work toward student directed learning. Similarly, Penelope described a supportive environment and perceived autonomy to make shifts to her teaching based on what she felt was necessary for her students.

The extent to which participants were expected by administrators to follow model curriculum emerged as a productive tension to discuss in response to the question of how participants translated equity practices to their teaching. McNeill et al. (2018) recognize that "teachers have an important role within a unique instructional context, as they interpret, adapt

and implement the curriculum." The authors take the perspective that teachers should be the "active designer of curriculum rather than solely an implementer" (p. 1457). Administration can have a significant influence on approach to curriculum, as demonstrated by the differing levels of oversight shared by participants in this study. Literature on the use of model curriculum in teacher professional learning suggests that when curriculum is used as a starting point or a resource it can allow teachers to focus on students and being responsive to their needs through pedagogical choices (Williams et al., 2019). For example, when used as a resource, Dailey et al. (2018) and Hayes et al. (2019) found that model curriculum supported teachers understanding of engineering design. However, teachers need to have an understanding of students' culture to make meaningful connections between curriculum and students ways of knowing (Cunningham & Carlsen, 2014b).

Alana and Eddie shared their struggle with enacting equity practices in their teaching because the focus of the professional learning lacked coherence with expectations in their teaching context which they reported as inflexible to teacher-driven changes in practice. Douglas et al. (2016) recognized contextual factors between two schools that led to only one successfully implementing engineering design and Lesseig et al. (2016) determined that structural barriers, such as established scope and sequence, can be a significant factor for integrating new practices. The findings from this study align with the literature suggesting that the focus of curriculum and the influence of school administrators are influential for success of reform efforts. If equity is not prioritized by those in positions of power, teachers can lack the support and autonomy to be responsive to their student's needs. The findings suggest that enactment of equity practices requires some level of autonomy to be an agent of change. Teachers, like Bryce, may decide to take autonomy regardless of administrative oversight. However, not all are willing to take

professional risks and should not be expected to do so in order to improve their practice. If teachers are not respected as autonomous professionals, they are limited in their ability to center students in their pedagogy and be responsive to the individuals in the classroom.

Productive Tension−Responsiveness to Students' Multilingual Assets

Participants' autonomy to support students' diverse language abilities emerged as a productive tension and a context specific example of how administrative oversight influences teachers' ability to be responsive to students' needs. Therefore, I chose to discuss responsiveness to students' language abilities as an example of autonomy. Language is an important aspect of culture and identity for students. Eddie and Carisa chose to focus their problems of practice on contextual challenges supporting English Language Learners in their classes, a topic relevant to many schools across the country. There are over five million students identified as English Language Learners in public schools in the United States and a wide diversity of programs designed to serve their learning needs (Sugarman, 2018). The expectation to address the needs of English Language Learners is recognized in the Framework, whose authors state:

> When supported appropriately, these students are capable of learning science through their emerging language and comprehending and carrying out sophisticated language functions (e.g., arguing from evidence, providing explanations, developing models) using less-than-perfect English. By engaging in such practices, moreover, they simultaneously build on their understanding of science and their language proficiency (i.e., capacity to do more with language) (National Research Council, 2012, p. 33).

Like other statements of reform, this language does not simply translate to classroom practice. Teachers need to learn to integrate culturally and linguistically informed pedagogies that allow for rigorous support of English Language Learners.

In this study, Carisa and Eddie shared very different approaches to supporting English Language Learners while teaching the same district mandated curriculum. They recognized language support as an equity concern in their classrooms. Eddie, a self-identified Latino and Spanish speaker, was encouraged by administrators not to teach students in their native language and grappled with the need to follow his supervisor's requests. This approach seemed in direct tension with his initial identity statement and ideas about equity where he described the need to support students by acknowledging that they need different levels of support. He struggled with the decision to enact practices that supported students understanding in their native language.

Scholars suggest that language diversity is not a deficit, but a resource. Godley et al. (2006) state "effective teachers build on students' linguistic resources, including the vernacular dialects they bring to class, in order to develop students' mastery of academic concepts and practices" (p.34). When students are supported in making use of existing language resources, including their first language, they can leverage prior knowledge and experiences as valuable opportunities for learning. Research suggests that teachers can be successful in supporting English Language Learners' science understanding when they "value emergent bilingual students' successes by acknowledging and celebrating emerging skills, building on the rich linguistic and experiential resources students bring in both in home and new language in order to optimize participation and facilitate understanding" (Kang et al., 2018, p. 40).

The data revealed that through dialogue with colleagues, Eddie grappled with ideas about supporting English Language Learners and demonstrated a shift in his practice by permitting students to use Spanish as well as English in their research presentations. Eddie made this small negotiation despite requests from his administrators to only use English when teaching. Post-interview data revealed that Eddie was grappling with the value of supporting both English and

Spanish languages in his teaching but was unsure of how to negotiate what he thought was good teaching practice and what his administrator requested of him. I recognize that this study represents a snapshot of the journey of thinking about equity and like the participants discussed in Hudley and Mallinson (2017), Eddie and others may benefit from continuing to think critically about student's native language use as an asset for sharing their ideas and deepening their science knowledge. Eddie's exploration of language as a cultural resource may require him to abandoned existing deficit views of multilingual use in the classroom. His ability to translate an asset perspective of language use to his teaching may be influenced by his scope of autonomy.

When teachers feel powerless to attend to their students' needs because of administrative oversight that is misaligned to their sense of purpose as educators, they can be faced with difficult professional decisions. Pantić (2017) suggests that perceived barriers for exercising autonomy can often be overcome. Eddie's new awareness of practices that value multilingual skills as assets for learning and his access to other teachers and resources that support this aspect of his professional identity may contribute to his scope of autonomy. This example highlights the importance of professional learning that supports teachers as autonomous professionals engaged in the social and emotional work of teaching. When engaging in critical equity-focused work, external communities can bolster those feeling unsupported in their contexts and empower them to be advocates for change. The participants who were able to translate new ideas about equity in their planning and their teaching practice demonstrated autonomy to do so in their content.

Research Question Three−The Science and Engineering Practices and Equity

The NGSS articulates the expectations for student engagement in the practices of science and makes an explicit call for equity in science education (Rodriguez, 2015). The SEPs and the attention to equity are two relatively recent significant shifts for national standards, despite many

years of literature recognizing the importance of integrating equity in disciplinary content areas (Geneva Gay, 2010a, 2010b; Ladson-Billings, 1995; Larkin, 2013; Windschitl, 2003). As explained in the design principles discussed in Chapter One, I engaged in this work recognizing that a decade after the release of NGSS, teachers continue to make sense of expectations for both engaging student in science practices and attending to equity in the classroom. To understand how teachers bridge these two focal points of NGSS, I was compelled to ask the third research question, "*to what extent are science and engineering practices and equity related components of teachers' practice?"*

Findings from this study align with previous studies suggesting that teachers struggle to integrate science practices and core science ideas with culture when they are not familiar with students' cultural backgrounds (Ladson-Billings, 1995), and that with support, such as opportunities for transformative professional learning (Johnson, 2011), or teacher development models that demonstrate how culture and science can be connected, teachers can learn to facilitate meaningful cultural connections (Bancroft & Nyirenda, 2020; Brown & Crippen, 2016). Each participant demonstrated understanding of how to align their teaching to at least one of the eight SEPs. This finding is not surprising as all participants had previous experience thinking about the SEPs in the GenerationSTEM program, where attention to the SEPs was a focal point of developing STEM learning experiences. The language of NGSS sets the expectation that teachers engage students in the SEPs, as active participants in the learning process and emphasizes that students do not learn science as secondhand observers. The engineering design challenges, laboratory activities, and collaborative inquiry-based projects that participants shared are examples of opportunities for students to do science and engage in the critical thinking

emphasized in the SEPs. To that end, all participants demonstrated the ability to plan and enact lessons that focus on the SEPs per the language of the NGSS.

Those who related equity and the SEPs decided to use high-leverage practices as tools for centering students' ideas. They demonstrated a strong sense of purpose for doing so, suggesting that they were able to progress in making sense of equity, and demonstrate autonomy to enact a change. The findings support Kennedy's (2016) assertion that teachers need to understand the purpose for the change in order to make shifts to their teaching that are otherwise comfortable and habitual.

Attending to Science and Engineering Practices and Equity with High Leverage Practices

Through the process of collaboratively thinking about opportunities to teach with an equity-focus, some participants were able to make decisions to enact practices that centered students. They enacted practices that are referred to as high-leverage in the literature because of their ability to be taken up across contexts and help teachers focus on student ideas with their knowledge of professional practice (Cohen, 2015; McDonald et al., 2013; Windschitl et al., 2018). Bryce started this work with a strong social justice orientation and demonstrated practices that centered his students' ideas. Bryce's work served as a model for others who were looking for examples of how to center students' everyday lives. Penelope and David identified opportunities to enact the practice of eliciting student ideas, a high-leverage practice intended to promote student engagement and learning for all students, particularly marginalized students or those reluctant to participate in reasoning and sharing ideas (Windschitl et al., 2018). Tom refocused his teaching on integrating students' stories and everyday experiences to enhance content connections and attend to their social-emotional well-being. Carisa was able to use summary tables as a support for students' synthesis of ideas. In the following section, I discuss

each example to understand how teachers demonstrated sense of purpose, competency, and autonomy for attending to the SEPs with an equity-focus.

High-leverage Practice Number One: Eliciting Student Ideas. Penelope demonstrated a strong understanding of chemistry and student engagement in the SEPs. She decided to make a shift to a specific lesson with the expressed intention of listening to and engaging with students' ideas. Penelope elicited student ideas about a local environmental issue, Asthma, which she recognized was meaningful to her students and their families. The decision to ask students what they noticed and wondered about Asthma and the connections between hospitalization rates and tree cover in their local region was a shift from the teacher-centered practices she was formerly using. She remained focused on the SEP *Analyzing and Interpreting Data*, however, her decision to enact an equity-focused practice caused her to select data from the local community and place students' connections to the data at the center of the lesson. The phenomenon of local Asthma rates was accessible and meaningful to students, leading them to the rich task of analyzing data to make sense of the phenomenon. Penelope's pedagogical shift was impactful for student engagement and interest in the lesson. She articulated a strong sense of purpose for enacting this practice as part of her efforts to center students' lives and advocate for issues that were important to them.

In a similar way, David made sense of elicitation as a strategy for "reimagining" and "refocusing" his teaching. David shared that one of his major goals for joining the community of practice was to gain ideas and resources for his "teacher toolbox." He accomplished this goal and emerged from the work recognizing that many of the best ideas about connections to content come from students. David's process of making sense of elicitation as an equity-focused practice, included learning about and trying an activity that started by centering students' cultural

experiences. He shifted his focus from what he could do as the teacher to make chemistry meaningful for students, to focus on what he and his students could do together. David invited students to share connections to chemistry from their each of their kitchens, opening up the opportunity for authentic connections to the content and practices of chemistry (Fickel, 2005; Johnson, 2011). David was initially very uncomfortable with how open-ended the practice felt, but ultimately was overwhelmed with the positive response he received from his students. He emerged from the experience looking for additional opportunities in his teaching to enact elicitation practices. David's "ah-ha" moment led to a deeper understanding of why focusing on students' ideas is essential and how small shift can led to more equitable practices (Kennedy, 2016).

David and others in the group held Bryce's problem of practice as an example of equity-driven teaching because it was intentionally designed to center student's cultural connections to the process of making coffee, an example of filtration. Participants responded positively to Bryce's work, seeing it as something they could also accomplish in their teaching. Bryce began the study with a strong equity focus and was enacting high-leverage practices such as elicitation with recognizing them as such. Bryce was seeking opportunities to be a critical educator in his context. Focusing on advocacy, Bryce developed a lesson that incorporated a local voting issue and math concepts from the Algebra curriculum. The math concepts were part of the required curriculum. However, the critical approach taken to integrate a social justice issue into the math classroom demonstrated Bryce's sense of purpose for teaching with an equity focus. The data suggests that Bryce recognized the role of teacher as much more than provider of content. By integrating social and cultural connections and valuing student's diverse perspectives Bryce's

work served as a model or eliciting student ideas focused on topics that challenge marginalizing practices in schools (Calabrese Barton et al., 2020).

High-leverage Practice Number Two: Summary Tables. Bryce's ability to recognize injustices in his context and support colleagues in the group in thinking about their own context specific practices, was meaningful for others. The occurrences of thinking about students' native language assets, described in Chapter Four, are examples of challenging injustices that are entrenched in everyday practices. Carisa was able to recognize lack of language support and decide to enact a practice to address her students' needs. In Carisa's problem of practice, she noticed that her students were having difficulty synthesizing ideas from the activities in a unit of study to draw important connections. She expressed wanting to use a practice that would help them see their success and be empowered to draw their own conclusions about big science ideas in a unit. Carisa shared two examples of summary tables that she enacted when teaching two units during the 16-week period. The two examples demonstrated how various activities from a unit can be summarized in one document to help students organize big ideas. The summary table column labels that Carisa chose to use are similar to labels recommended by Windschitl et al. (2018). She begins with listing the name of the activity as discussed with students, then worked with students to summary what they observed and noticed in the activity with respect to the big idea. In the third column, Carisa asked students to think about the causes for what they observed and noticed. She added an emphasis on data analysis, by asking "what does the data say?" With this modification she emphasized the focus on SEP *Analyzing and Interpreting Data.* The final column, "How does this help us understand...? was completed though dialogue with students. These examples of Carisa's use of summary tables supported students in synthesizing their ideas. She recognized that the practice helped her address her problem of practice, which strengthened

her purpose for using it in the future. Overall, the four teachers discussed here, Penelope, David, Bryce, and Carisa, articulated how they used high-leverage practices to address issues of equity in teaching the SEPs. They were each able to express a sense of purpose for enacting a practice, suggesting that both sense of purpose and understanding of practice were important for making the shift in their teaching.

Attending to Equity Beyond the Science and Engineering Practices

Participant's selection of problems of practice resulted in topics that I as the researcher, may not have focused on and which may not be central in the education literature on equity pedagogy. Brenner et al. (2016) noticed this consequence when working with teachers on action research questions regarding equity in their classrooms and determined it to be a negative consequence of participants autonomous selection of topics. I suggest however that unforeseen connections between teachers practice and equity are generative and necessary for thinking about myriad implications for equity across contexts. Teacher's ideas about equity are essential for shifting practice towards students ideas (Coburn & Penuel, 2016).

Tom focused on social-emotional learning needs of his students as an equity-focused problem of practice. As a teacher who was passionate about his content area and enjoyed focusing on content specific connections to students' lives, Tom's focus on social-emotional learning led him to recognize that attention to the culture of the classroom and individual student social emotional well-being is an important factor in being able to attend to the SEPs. Like Tom, scholars in the field of education are attentive to social emotional health of students and increased attention to social-emotional learning as equity practice is represented in the literature (Duane et al., 2021; Simmons, 2019). Tom's problem of practice exemplifies the importance of attending to teacher's ideas about their practice when engaging in professional development.

I chose to discuss Bryce's work as "beyond the SEPs" because Bryce's problem of practice focused on opportunities to engage students in advocacy within their communities. Bryce's lesson, which served as an example for others in the group, elicited student's cultural connections to the process of making coffee, an example of filtration. Bryce described teaching with student ideas and building on the connections that they made. Interestingly, Bryce was not aware that the practices being implemented were considered high-leverage practices. Focusing on advocacy, Bryce sought ideas from the group that would help students become aware of opportunities to be advocates for change. The group helped Bryce learn about resources for taking action on environmental issues where their knowledge of filtration in could be applied. In the second example of advocacy that Bryce shared, the issue of voting rights became inspiration for looking at mathematical data and models within the context of a current social justice issue that influenced the local community. The critical approach taken to integrate a social justice issue into the math classroom demonstrated Bryce's sense of purpose for teaching with an equity focus and competency to make meaningful connections to content and the SEPs. Findings suggests that Bryce recognized the role of teacher as much more than provider of content. This work responds to the call to select teaching practices that "challenge and disrupt historically entrenched marginalizing practices" (Calabrese Barton et al., 2020, p. 493).

Teachers are likely to enact new practice when the understand the reason for the practice. Kennedy (2016) states "enacting a new idea is not a matter of simple adoption but rather a matter of figuring out whether, when, and how to incorporate that new idea into an ongoing system of practice" (p.11). Scholars suggest that the decision to take up new practices is subject teachers social, professional, personal, and context-based subtleties. Tom and Bryce recognized specific aspects of their teaching that extended beyond current applications of high-leverage practices in

the literature, suggesting that teachers are valuable knowledge creators of classroom practice and should be integral to the development of research-based practices in the field of science education. I suggest that participants were successful in progressing with their understanding of equity practices because they were dedicated to the reason behind the change and engaged in a professional learning model that positioned them as knowledgeable professionals.

Summary

This chapter was about understanding how the findings responded to the three research questions for this study. Analysis of dialogue from community of practice sessions revealed productive tensions that led to participants noticing components of teaching with equity, deciding what to do with new knowledge, and in some cases enacting practices to attend to equity in their teaching context. The specific tensions that emerged from teacher's noticing and reflecting on problems of practice included recognizing various aspects of equity pedagogy: 1) multiple definitions of equity, 2) equity as inclusion involves centering students' ideas, 3) awareness of deficit language, 4) scope of autonomy to be agents of change, and 5) valuing students' multilingual skills. Discussion of these tensions revealed the aspects of equity that participants noticed and decided to work on.

Those who were able to relate science and engineering practices and equity in their practice selected high-leverage practices to center and support students' ideas. I discussed the specific examples of enactment including forms of eliciting student ideas and supporting ideas with summary tables. In addition, I focused on teaching that went beyond the SEPs to engage students in advocacy and focus on their social emotional well-being.

Each participant started this study from a different point in thinking about equity and progressed in their own way, supported through collaborative engagement within the community.

I contend that participants who demonstrated sense of purpose, competency, and autonomy for enacting practices were most successful in enacting practices that attended to equity. This finding supports Kennedy (2016) assertion that teachers are more likely to enact a practice when they understand the purpose of the practice. The outcome of this work suggests that with opportunities for sensemaking in a collaborative community, teachers may notice and attend to equity and develop a stronger sense of purpose for centering students. If motivated to do so, they can reason with new ideas and decide what to do next. High-leverage practices can serve as tools for centering students' ideas and developing teachers understanding of why equity is important and how to attend to equity in practice.

Chapter Seven: Implications and Conclusion

I set out to understand how ten teachers from ten different schools, located in two neighboring states, made sense of equity through collaboration in a community of practice. In designing and implementing the professional learning experience, I drew upon principles of teacher professional learning and literature in the field regarding NGSS reform and equity focused professional learning opportunities. Over a 16-week period, teachers dedicated time and effort to learning from one another and grappling with new ideas about equity practice, through discussion of sharing self-selected problems of practice. They explored their existing ideas about equity, made sense of new ideas, and decided their next steps in planning and enacting teaching with an equity lens. As the researcher, I noticed occurrences where individuals made sense of new ideas and learned from the productive tensions that emerged throughout the analysis of data. I drew upon my own experience as a teacher educator and my knowledge of the field to engage in this work and deepened my understanding of addressing equity within and across contexts through my role as facilitator in the community. The findings suggest that participants were able to engage in the generative work of sensemaking about equity through a collaborative community of practice and some were able to enact practices as an outcome of their sensemaking process. Teachers' sense of autonomy was consequential for enacting shifts to their teaching. I contend that teachers need to be intentional about planning and enacting practices that center students' ideas and cultural assets when teaching the SEPs. The shifts that teachers were able to make while engaged in a 16-week community of practice, suggest implications for supporting in-service teachers with equity practice, specifically with respect to high-leverage practices, and raise important questions for future research.

Normalizing Equity in Teacher Professional Learning

As detailed in the Chapter One, there is a pressing need to support teachers with professional learning opportunities where they can notice widespread inequities in education and make sense of why and how to enact practices that meet that goal. Professional learning has become increasingly dictated by administrators and school-based initiatives, and teachers report reduced autonomy to select how school-based development time is spent (Brito & Ball, 2020). During times of reform, teachers can be inundated with new expectations and approaches to teaching intended to support research-based shifts in practice (Penuel et al., 2007). Literature suggests that teachers will take up change and dedicate time to making sense of new ideas when they understand the purpose for doing so (Kennedy, 2016).

This study suggests that some teachers will go above and beyond their contracted teaching hours to improve their practice. However, I contend that if equity is to become a central focus of the profession, teachers need opportunities to engage in critical professional development that positions "teachers as politically-aware individuals who have a stake in teaching and transforming society" as part of their professional learning (Kohli, Picower, Martinez, & Ortiz, 2015, p. 9). Currently, most often critical professional development takes place beyond school-based professional development, as common models for school-based professional development include administrator-driven or top-down approaches to determining what gets prioritized. There are important take-aways from the design-based research model implemented in this study that can inform critical, equity-focused professional development in both school-based and "underground" spaces (Kohli et al., 2015).

Implications for Design-based Research in Critical Professional Development

Four design principles helped frame this work in the context of science teacher professional development and ground the design and implementation of the community of practice in research-based practices. Design-based research can realign the roles of researchers and classroom educators so that the individuals interacting with students on a daily basis take ownership of innovations to meet the needs of their students (Fishman et al., 2013; Stromholt & Bell, 2018). This community of practice model was unlike commonly used models for professional development in a number of ways that are worth reflecting on for future work.

The first principle I considered in the design of this work was how research-based practices for teacher professional learning informed what we did. I drew upon my professional experience with teacher education and literature in the field of science teacher professional development to understand research-based practices and their outcomes across contexts. This included consideration of the balance between content and pedagogy, the importance of participants understanding the purpose of the work, the knowledge of how teachers learn and decide to take up new ways of teaching, and the value of ongoing, sustained collaboration. My knowledge of the field, experience as an educator, and ability to continue to work with educators from past professional development experiences was noteworthy. The data suggested that the participants in this study were able to accomplish meaningful outcomes due to their sense of purpose for engaging in the work. Their position as volunteers, interested in growing their equity pedagogy and working with colleagues with whom they had positive interactions with in a former professional development experience, should not be overlooked. As the data suggested, participants took up this work with varying levels of consideration of equity pedagogy. The ways in which they interacted and pushed each other to deepen their thinking was important. Across

the field, teachers are asked to engage in many development opportunities and as a result are often more engaged in some initiatives than others (Penuel et al., 2007). The participants initial approach and framing of the work was consequential for the outcomes they achieved within the 16-week period. The findings align with the approach being taken up in other current research-practice partnerships with schools that center teacher's beliefs and experiences as professional educators and engage in sustained work through collaboration (Coburn & Penuel, 2016; Coburn et al., 2013; Fishman et al., 2013; Penuel & Potvin, 2021).

The second informative design principle I used to define this work was based on a deep body of literature grounded in Vygotsky's (1978) social constructivism and Wegner's (2010) community of practice frameworks that suggest individuals learn best in social structures where they can engage in dialogue and think critically together. I was careful to consider the components of the community of practice and the routines we would use to place boundaries on our work together. This included ensuring that all members of the group were heard and had equal time to work on a problem of practice that was meaningful to them. I intentionally positioned myself as a member of the group, contributing to the discussion during the participant's presentations of problem of practice to the same degree as others. I thoughtfully created spaces for sharing ideas and resources where anyone could contribute and offered resources in response to participants needs. This approach to the community of practice space was informed by my professional experience participating in both didactic and collaborative models of professional development and facilitating collaborative spaces for learning as a teacher educator.

As a proponent of equity as a core component of teaching, my beliefs about teaching as student-centered work were apparent in the approach I took as facilitator of the community of

practice. The third design principle, states that teaching is student-centered work and draws from a body of literature in the high-leverage practice movement that places students and their ideas at the center of the work of teaching. I affirm that teachers can "honor students' sensemaking repertoires" (Windschitl et al., 2018, p. 11) through specific teaching practices and those beliefs were an integral part of my purpose in engaging in this study. This lens on the value of student ideas was key to the way in which the study was designed and implemented and is a critical component to consider in future iterations of critical professional development models.

The fourth central principle that guided this work was the construct of teacher agency. I drew upon literature suggesting that teachers are agents of change and when they approach teaching as action oriented, dynamic, cultural, and emotional work, they can affect change in their professional contexts with the goal of improving learning opportunities for students. Teacher agency is rooted in the idea that teachers are both knowledge creators and experts at adapting their practice to their students' needs (Cochran-Smith & Lytle, 1999; Hammerness et al., 2005). I engaged in this work from a teacher leadership perspective, recognizing the successes of many educators I have worked in my career who engage in their work as agents of change. As the data from this study suggested, some contexts are more supportive of teachers in agentic positions than others. However, most participants were able to make autonomous decisions despite their administrative and contextual constraints. My affirming stance that participants in this study were capable of strengthening their sense of purpose for equity pedagogy and demonstrating competence to align equity to standards-based teaching may have contributed to their beliefs in the ability to affect change.

Reflecting on the design principles that informed this work, I will consider adding a fifth principle to future implementations to specifically highlight historical inequities that undergird

systems of education in this country. By grounding this work in Eurocentric practices and racist policies that create inequities in institutions of education, I the fifth design principle would make explicit the importance of identifying, addressing, and dismantling inequitable practices in classrooms. In addition, in future iterations of the community of practice implementation, I would extend the first few sessions to include discussion of historical and present-day conditions that create inequities. That said, I do not consider the work started with the group of participants in this study to be complete and envision opportunities to engage in exploring the conditions that create inequities in future work with this community of teachers. There were several important concerns raised as participants presented their problems of practice. The structure of the time spent in the online sessions was intentionally fluid to be responsive to participants needs, however, future time together can be allocated to more deeply unpacking the contextual and localized concerns that participants raised. One example is David's hesitation to address student's concerns about racism. Another example is the use of deficit language when speaking about students and families. Recognizing inequities and changing practices to be intentionally equity-focused requires time, reflection, and careful consideration. It is an ongoing and generative process, through which I continue to learn alongside the participants in this study and in future work. I recognize that the results of this work contribute to thinking about equity focused professional learning in school-based settings as well as in underground spaces.

School-based Equity Work

In-service teachers frequently cite the need to collaborate with others as an important component of improving their practice and literature on professional learning supports collaborative models for professional development, centered around what teachers identify as important areas of focus (Desimone et al., 2013; Hawley & Valli, 1999). However, teachers also

cite lack of time to engage with others (Cheung et al., 2018; Supovitz & Turner, 2000). When school-based initiatives are prioritized, school leaders can make time for teachers to collaborate. This is evident in the widespread use of professional learning communities and frequency of full day professional development workshops that target mandated and administrator-driven training (Banilower et al., 2018). Districts are placing more attention on equity in response to national calls to attend to issues of social justice in schools. Some are forming "equity-committees" to review opportunities for improvement. As school-based groups begin to take shape, their success will be dependent on the time dedicated to them, how they are implemented, and the extent to which they center students and attend to issues of social justice and systemic oppression in their work (Villavicencio et al., 2020). Current attention to equity presents opportunity for meaningful change. However, as participants in this study shared, the culture of collaboration, degree of administrative support, teachers' agency to enact change in classrooms, and the support they have in making sense of why and how to implement change, are all factors that influence the outcome of efforts.

Teachers can continue to find meaningful connections through "underground spaces" like those described in Kohli et al. (2015). Groups that are external to individuals' teaching contexts can help teachers find fulfillment and support from like-minded individuals. As demonstrated through the work done in this study, technology may be used as a tool for collaboration and networking across contexts to inform the work of individuals within contexts (Dede et al., 2016). In addition to these opportunities, teachers need school-based support to address context specific concerns with colleagues within the cultural-social spaces where teaching occurs. Individuals working collaboratively within school-based contexts have the

potential to prioritize collective action around issues of equity (Eteläpelto et al., 2013; Pantić, 2017).

Implications for High-leverage Practices

The high-leverage practices movement provides practices that can be enacted across contexts to support student-centered equity-focused teaching. They shift teachers practice away from acquisition models of learning and provide pedagogical moves that teachers can use to engage students and their ideas in the learning process. This study suggests that specific teaching moves can be learned and applied across contexts. Teachers may be able to enact high-leverage practices without understanding the importance for centering students' ideas. However, findings suggest that teachers benefit from understanding why the practice is beneficial to student learning and why culture should be centered in the learning process. As Kennedy states, "enacting a new idea is not a matter of simple adoption but rather a matter of figuring out whether, when, and how to incorporate that new idea into an ongoing system of practice which is already satisfactory and may also be largely habitual" (p. 11).

Teachers need to know not only how to enact high-leverage practices but why practices are important in order to be responsive to students' ideas in the classroom. Learning to enact high-leverage practices is essential across the continuum of teacher education, however, void of a sense of purpose that includes equity for the benefit of students learning, practices are in danger of maintaining classroom routines with somewhat increased opportunities for student voice, only superficially valuing student experience, and being seen as just another reform. Making sense of how high-leverage practices can support all students with deep conceptual understanding can include support for making sense of why they are inclusive practices. Philip et

al. (2019) caution that "generic methods for preparing all teachers to use generic methods to then teach all students"

(p.10) supports a reform agenda without emphasizing understanding the underlying justice orientation of the work. The findings from this study suggest that the individuals most capable of seeing opportunities for attention to equity in their local context and centering them, with connection to the SEPs and disciplinary content, maintained a strong sense of purpose for why justice-oriented teaching practices were important. Therefore, truly enacting high-leverage practices with the purpose of doing equity-focused, justice-oriented work in classrooms, requires that teachers understand why the practices are important as well as how to enact them locally. As Calabrese Barton et al. (2020) contend "justice-oriented HLPs require not only intellect, creativity, and reflection, but also are filtered through nuanced understandings grounded in criticality" (p. 493). I suggest professional learning models that advance high-leverage practices as equity-pedagogy include design components that address teacher's understanding of why and for what purposes high-leverage practices are enacted.

Striving for Equity as More Than Inclusion

As Calabrese Barton and Tan (2020) express, framing equity as inclusion suggests that students who have been historically disadvantaged be granted membership in a learning community where there is equal access for all students. An equity as inclusion approach requires that rights are extended from those who are included to those who are not. The privilege to invite students to equal learning opportunities perpetuates inequities and continues to position some students as other. Calabrese Barton and Tan (2020) argue that focusing on inclusion alone does "little to disrupt systemic inequalities in classrooms" and that all students have a "rightful presence" in the classroom. Teachers need support "in developing strategies to notice and make

present the lives of their students as integral to disciplinary learning, and as powerful lenses for exposing/restructuring the injustices that position youth as marginal to learning" (p.438).

When supported in thinking about injustices inherent in schools, teachers can identify and make visible components of teaching that need to be addressed. Participants in this study discussed issues of mandated curriculum, problematized approaches to teaching students in their native language, and identified missing voices and representation in disciplinary curriculum. For example, they noticed and grappled with the limits that mandated curriculum placed on Alana's ability to engage students in the SEPs and collectively agreed that, while difficult, Alana should advocate for what she recognized was best for her students. Through discussions about students' native language, participants recognized that English only was an exclusionary practice and began to make sense of how to shift teaching to value multilingual abilities. Together, teachers identified aspects of curriculum where representation of historically marginalized groups was absent. As Penelope shared, she began to think about how the student sees the lesson and how practices can be shaped to bring in more of students' ideas and background.

Participants identified places where historically marginalized voices should replace commonly shared stories of discoveries and advances in STEM disciplines. By critically analyzing language that defines equity, as participants did with the NGSS definition of equity, teachers can become aware of problematic language and approaches to equity practice that perpetuate systemic injustices. The significance of the collaborative sensemaking achieved by participants in this study suggests that when provided opportunities to notice inequity and opportunities for improvement, teachers can progress in thinking about equity as more than inclusion and help build understanding of what equity looks like in practice.

Limitations

Acknowledging and accepting the limitations of this study is both humbling and inspiring as it motivates me to continue the work. Due to the time-frame of this study and restriction on visiting classrooms due to safety concerns with the spread of COVID-19, I was not able to observe teachers enacting equity practices in classrooms with students, where they enact "in the moment decision making" (McDonald et al., 2013). The findings rely on participants' self-reported accounts of their teaching practice and contexts. When participants enacted practices they reported personal interpretations of students' responses to pedagogical shifts. I recognize that self-reported data can result in discrepancies as participants can be influenced by the desire to appear successful, which may cause them to report more preferable outcomes (Gonyea, 2005).

Study participants represent a group of teachers selected because of their common experience participating in a previous professional learning opportunity where they demonstrated dedication to improving their practice and engaging in collaborative spaces. The circumstances of this convenience sample resulted in findings that are not generalizable to others. In addition, my position with the GenerationSTEM professional learning opportunity afforded me the opportunity to build on a former positive experience with participants which may have influenced their participation in the study and the types of dialogue they engaged in while participating in the community of practice.

Opportunities for Future Research

The collaborative learning that took place during this study is a snapshot of the ongoing journeys of ten teachers learning to enact equity practices. While all participants progressed in different ways with thinking about the purpose of equity and ways to enact equity in practice, their journeys are far from complete. Continued efforts will support teachers seeking to unpack

deeply embedded injustices that are enacted in schools in obvious as well as mundane and invisible ways (Calabrese Barton et al., 2020). Participants are committed to continuing to work together and requested additional rounds of discussion using the tuning protocol structure. I plan to continue this work with participants from this study and extend additional opportunities to other teachers.

Important questions emerged from productive tensions in this study which can be explored through future research. First, continuing to understand the extent to which in-service teachers can learn to enact equity-focused practices and recognize reasons for centering students' ideas will contribute to the understanding of how in-service teachers can be supported in learning to enact equity practices. Extensions of the model used here may include classroom observations and collaborative reflections with teachers, as a response to the need for research that leads to deeper understanding of how teachers enactment of equity-focused practices influences students' academic success (Sleeter, 2011).

Continued inquiry into how high-leverage practices can be used to support justice-oriented teaching within existing educational structures will strengthen understanding of the use of high-leverage practices as tools for advancing equity-focused pedagogy. The findings of this study suggest that teachers need to have some level of dedication to equity in or to learn about it as a new idea and grapple with what practices look like in their classrooms. The participants most comfortable with enacting practices could articulate understanding of oppressive and unjust structures in education. In future work, it will be important to heed concerns that high-leverage practices may simply become another reform effort functioning within oppressive systems of education if underlying attitudes and beliefs about students are not addressed (G. Gay, 2010; Philip et al., 2019).

This work highlighted systemic practices such as the use of deficit language about students and families which can be further explored. Despite sharing a generally affirming and positive view of improving teaching practice to be more inclusive of all students, some participants used deficit language to describe occurrences with students in their classrooms. The phenomenon of deficit thinking has been widely studied in education literature, yet it persists. Future design-based research studies can focus on deficit thinking and support teachers in deconstructing deficit language. Through opportunities to develop understand of why deficit language is pervasive, teacher may notice the systemic oppression perpetuated through such talk, and decide to abandon it (Garcia & Guerra, 2004).As teacher's unpack deficit thinking and systemic inequities, opportunities to engage with and learn about students, their families, and communities may support shift away from deficit thinking and reposition their student's family and community-based assets as valuable for learning.

Current justice-oriented work in communities can serve as a model to provide teachers with opportunities to learn about students' culture, families, and communities, so that rich cultural experiences can be centered in teaching the SEPs (Calabrese Barton & Tan, 2019). These efforts are contextual and can be taken up by teachers working collaboratively with community members, administrators, and students to deepen connections between curriculum and student's everyday lives. Future research can consider how all educators can be supported in centering students, not as an afterthought to what is expected to successfully implement curriculum, but as the central component of practices in science education.

As participants take their experiences with this community of practice into their local contexts, join equity committees, serve as advocates for students, and bring attention to unjust practices, they can extend the work into their local communities, while remaining grounded to

the network of individuals who push their thinking and practice. Based on the results of this study, I am compelled to ask how professional learning experiences that attend to equity-focused teaching practices can become normalized in schools. It became apparent from specific interactions of participants with their administrators, for example Eddie and Alana, that involving administration in equity work is essential. Future research may explore professional learning opportunities for administrators to support equity and to ensure that teachers professional experience is central to the design of professional development opportunities.

The problems of practice and the dialogue between teachers that occurred in this study uncovered productive tensions, each of which can be explored in greater depth contextually and as persistent concerns in science education. While it is necessary to identify a start and end point for the purposes of this study, the work represented here is unfinished. Future research may focus on unpacking each of the tensions with the goal of supporting teachers in centering equity-driven, student-centered learning opportunities.

Concluding Remarks

The purpose of this professional learning opportunity was to support teachers in making sense of equity when teaching the SEPs and their agency when attending to students' needs in the classroom–the spaces where all students should have support to deepen their understanding of the world around them. This opportunity provided teachers a space to notice aspects of their teaching that they wished to improve and make sense of practices that consider students and their lived experiences, culture, and language as assets for learning about the world around them. The SEPs are intended to provide students with the opportunity to engage in the activities in which scientists and engineers engage. However, void of connections to how students make sense of the world–their cultural resources–the SEPs are in danger of becoming yet another reform. Science

education is about supporting students in making sense of the world around them; therefore, everyday lives must be viewed as resources. High-leverage practices have the potential to help teachers recast student ideas as the focus of learning. However, practices should be implemented with purpose and recognition of why they are valuable tools for deconstructing historicized injustices that permeate classroom practices. Ongoing research will contribute to understanding how practices are used by in-service teachers to center students' ideas as the focus of instruction.

Rudolph (2019) asserts, "if fundamental changes aren't made to how we prepare teachers and what we value as the goals of science education in the United States, the NGSS will almost surely face the same fate as the laboratory method, the scientific method, science as inquiry and all the other variants of scientific process that came before" (p.224). The findings from this study suggest that teachers can learn to center students and advocate for what they recognize students need to be successful learners. Focusing on equity as a central component of the new vision for science education requires noticing, questioning, and changing oppressive practices. Through collaboration with other professionals, teachers can make space for critical conversations about how to center students and their needs as the most crucial focus of the profession.

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Appendix A

Pre-interview Protocol

Thank you for volunteering to be part of this community of practice and for taking the time to speak with me.

1. I want to start off by listening to you describe yourself as an educator. Please tell me about yourself as a teacher.
    a. How does your identity as a teacher influence your work?
    b. Can you think of events, teachers, experiences in your life that contributed to this?
    c. How does your teaching identity influence your work?
2. I am interested in hearing about what you have been thinking about and doing. Please think about a time or event in the last few weeks when you have done something, or something has happened that has been important to you in thinking about your teaching?
    a. Tell me about this.
    b. Anything else?
    c. Where were you?
    d. When did this happen?
    e. Why/How was it important? (What difference did this make to you?)
3. You are a graduate of the GenerationSTEM program. What has your experience been since you finished the program?
        a. Is there anything positive that stands out?
        b. Is there anything that needs improvement that you want to share with me?
        c. Is there anything specific that stands out from the program that influenced your teaching?

4. Can you describe something that you so in your classroom now that you did not do 6 months or a year ago? (other than teaching online)
5. Please think about the students in your classroom and how they engage with one another. Can you "paint a picture" for me of what your classroom looks like and sounds like on a typical day.
6. We use a fair number of what I will call "buzz words" in education, terms that quickly get picked up by many but sometimes lose their initial intention. I consider the acronym STEM to be one of these terms now. "Equity" is another term that is being used more often in education. Can you describe to me what you think of when you hear the term equity?
7. To what extent does a student's cultural background play a part in their learning process?
    a. Can you provide an example of when culture was an important component of a science lesson in your classroom?
8. Reflection is a big part of what we do as teachers. Anyone who has been in the profession for a few years will likely describe a cycle of new initiatives, often including new ideas or practices, that they have experienced. Learning new practices or ideas can take time. Can you describe the process that you go through when you are learning a new idea or new practice as a teacher?
    a. Do you describe yourself as someone who collaborates well? Do you prefer to spend time with new ideas on your own?
9. (Show NGSS SEPs) Please think of an example of a class activity where students use a science practice or an engineering practice.
        a. Tell me about the activity

   b. In what ways did students interact with the data?
   c. Was there ever a time when students analyzed the data in very different ways?

10. We are in a period in education where we talk a lot about core practices. We have the Common Core State Standards for ELA and Math, NGSS for science and engineering. In your own words, please describe what the "core practices" are and why there is an emphasis on core practices in education.
11. This Community of Practice is designed to be a place where a small group of us can learn from one another through discussion of topics such as the science and engineering practices and equity. Is there anything that you would like to glean from this group in particular?
    a. What do you consider your strengths entering this group?
    b. Are there any areas of your teaching practice that you wish to work on specifically?

Thank you.

Appendix B

Tuning Protocol: Teaching with Attention to Equity

This tuning protocol can be used to facilitate discussion within community of practice groups, professional learning communities, and teacher development spaces where individuals seek deeper understanding about planning for and teaching with attention to equity. Ideally, individuals meet regularly so that the responsibility for sharing a lesson or activity can be rotated among group members over a series of meetings.

Selecting a Lesson or Activity for Discussion

Select a lesson that you wish to improve or wish to receive feedback on through an equity lens. The lesson should be detailed enough to elicit good discussion. Include the student learning objectives, a description of the activities in which teachers and students engage, the standards being addressed, and all necessary information to provide the members of the community a sense of the goals for the lesson.

You may choose to focus on a specific aspect of the lesson to receive feedback. Develop a question that will drive the respondent's discussion. For example:

"How can I differentiate for the members of this particular class?"
"How might I implement the lesson to support the students who seem disengaged?"
"How might I change the "hook" to engage diverse students in the content?"
"How can I make sure that my assessments are equitable?"
"How can I incorporate diverse cultures and experiences into this lesson?"

Facilitating the Protocol (30 minutes)

Roles

- Presenter: individual whose lesson is being discussed by the group
- Facilitator & Timekeeper: individual who keeps the conversation flowing according to the group norms and provides helpful reminders to participants on timing
- Respondents: collaborative group members. Outside perspective is critical to the effectiveness of this protocol; therefore, the other individuals in the community of practice will help the presenter deepen their thinking throughout the steps below.

Steps

1. **Presentation (10 minutes).** The presenter describes the context for the lesson, without interruption.
   - Information about the students and/or the class — what the students tend to be like, where they are in school, where they are in the year. Descriptions of the students grounded in person-first and affirmative language is most appropriate.
   - Description of the lesson including the details that help the respondents gain a picture of how the lesson is currently planned and implemented.
   - Focus the respondents on a specific aspect of the lesson that you wish to develop, by closing with a direct question(s) of the group. (The facilitator will post this question(s) for the group to see).
2. **Clarifying Questions (5 minutes).** Respondents have an opportunity to ask "clarifying" questions to get information that may have been omitted in the presentation that they feel

would help them to understand the context. Clarifying questions are matters of "fact." The facilitator should be sure to limit the questions to those that are "clarifying," judging which questions more properly belong in the warm/ cool feedback section.

3. **Discussion – Warm and Cool Feedback (15 minutes).**
Respondents share feedback with each other while the presenter is silent. The feedback generally begins with a few minutes of warm feedback, moves on to a few minutes of cool feedback (sometimes phrased in the form of reflective questions), and then moves back and forth between warm and cool feedback. Warm feedback may include comments about how the work presented seems to meet the desired goals; cool feedback may include possible "disconnects," gaps, or problems. Often participants offer ideas or suggestions for strengthening the work presented.

   The facilitator may need to remind participants of the presenter's focusing question, which should be posted for all to see. Presenter is silent and takes notes.
   Constructive responses may begin with the following prompts:

   - "I wonder what would happen if _____"
   - "If the goal is _____, then it would seem important to _____."
   - "This makes me think about _____."
   - "I agree that _____, but _____..."
   - "I disagree that _____, because _____...."

   Respondents may provide statements or questions that tune the presenter into areas of disconnects, gaps, dilemmas, or other experiences that connect to the focus question. Respondents may also connect the ideas under discussion to other research, similar practices, or other good leads. Individual experiences may be used to support a point; however, the respondents should be careful to keep the conversation focused on the presenter's context and focus question(s). **Remember that the goal is to advance the presenter's thinking about their teaching with attention to equity.**

4. **Reaction (5 minutes).** The presenter responds to any aspect of the discussion that they choose. During this step, respondents may not speak unless invited by the presenter.

5. **Debrief (optional).** Afterwards, participants may debrief the process, but the facilitator may remind everyone that discussion about the presenter's work has ended.

Adapted from:

- McDonald, J. P., Mohr, N., Dichter, A., & McDonald, E. C. (2015). *The power of protocols: An educator's guide to better practice*. Teachers College Press.
- School Reform Initiative (2017). Tuning for Equity Protocol https://www.schoolreforminitiative.org/download/tuning-for-equity-protocol/
- Settlage, J., & Johnston, A. (2014). The crossroads model. *Educational Leadership, 71*, 67-70.

Appendix C

Post-survey Questions

1. When we started this work together I asked you to think about what equity means to you as a teacher. Have your ideas changed at all? If so how? Please explain and feel free to describe specific discussions that influenced your thinking.
2. What is your understanding about why science educators are currently so focused on the science and engineering practices (SEPs)? In other words, what's the big deal about the SEPs?
3. How do you think about the connection between the science and engineering practices and equity?
4. This community was designed to provide you with the opportunity to choose a problem in your teaching practices and talk about it with the group. Please share your thoughts about the structure of the group and the use of the Tuning Protocol.
5. Thinking back on the past 9 sessions, were there any specific times in the discussion when someone said something that really impacted your thinking? Please describe this discussion and why it resonated with you.
6. Are there specific resources that you learned about from group members that will be especially helpful to you?
7. After spending time with this group, how do you intend to implement some of what you have learned about equity into your teaching?
8. Is there anything you wish you had time to talk about more deeply with this group?
9. Is there anything else you wish to share with me?
10. Please type your name.

Appendix D

Survey responses - Question Four

This community was designed to provide you with the opportunity to choose a problem in your teaching practices and talk about it with the group. Please share your thoughts about the structure of the group and the use of the Tuning Protocol.

Penelope I like how everyone can have a voice, how all voice are (usually) acknowledged and how it's set up so that it focuses your attention on a tangible problem rather than on emotions surrounding it. It's growth oriented and I like that.

Eddie The Tuning Protocol was an outstanding way for teachers to learn from teachers. As Billy mentioned, a quote from the Bible, Proverbs 27:17 "Iron sharpens iron." Occasionally, instructional coaches are too removed from the classroom, so they cannot offer much practical support. I think having teacher's problem solve their own issues is conducive way to exchange ideas and grow from one another. In a way, it even parallels the SEPs. Asking questions, using models (lesson plans), "planning and carrying out Investigations (trying out new things), analyzing and interpreting data (looking at student work and progress), "obtaining, evaluating, and communicating Information" (reflecting on the lesson).

Carisa The protocol allowed us to keep conversations focused on the main goal and to do so in a timely fashion. Everyone in the group respected other ideas as well as contributed suggestions in a very respectful manner. I can only speak for myself, but I think in general, we all felt pretty comfortable sharing our ideas

and providing suggestions.

Lucy I thought the structure was great! It made it a safe environment, free from judgement. The timing made it very fair.

Joyce I love the fact that we stayed focused and on topic and that each of us had an opportunity to share and receive feedback.

David I thought I knew what it was about for the first two Zooms, but then realize, I was over-focused on lesson 'improvement' but not within the lens of equity. It allowed me to step back and take a deeper reflection of my own lessons and practices.

Kathryn I thought the tuning protocol was a very positive experience. We're now using it in my STEM PLCs to share problems and challenges that we're having in our individual schools and grade levels. My district has also established an equity steering committee and I have shared the tuning protocol with the group as well.

Tom I believe that the tuning protocol is a great tool to keep the presentation and subsequent conversations flowing. The timeframe in the presentation allows for participant feedback, and meaningful interaction between the presenter and their audience. It was a very fluid experience.

Appendix E

Carisa's Summary Table Examples

Wildfire Module: Summary Table			
Activity	**What did we observe? What did we notice?**	**What is causing these patterns or observations? What does the data say?**	**How does this help us understand wildfire hazards?**
Activity 1: Feelin' Hot, Hot, Hot! (Investigate the phenomena of wildfires in the western part of the United States)	-wildfire occurring close to homes -some trees are green, and some are dry -smoke is traveling upward (direction of the wind) -most wildfires occur in western US	-there has been an increase in wildfires since 1980's -many wildfires occur near major cities -people with respiratory illnesses, older people, small children can be greatly affected	-we should use more renewable energies -prevent wildfires from happening when we do bonfires -cigarettes/matches must be safely disposed (away from dry trees)
Activity 2: Earth, Wind, and Wildfire (Investigate the roles that different factors play in wildfire spread)	-wildfires move in the same direction and speed as the wind -18,000 acres burned in Sacramento, CA	-wildfires are caused by heat, fuel, and oxygen -heat sources: sun, lightning, matches -fuel sources: leaves, grass, trees, shrubs -oxygen source: wind -85-90% wildfires are caused by humans (bonfires) -warmer climate and weather patterns also contribute to wildfires	-humans should take precautions when doing bonfires -increase in wildfires can decrease food resources, loss of shelter for animals and loss of homes for humans
Activity 3: Growth of a Wildfire (Investigate how wildfires behave when fueled with different vegetation)	Different landscapes have different types of vegetation: grass, shrubs, small/large forest litter. Different vegetation types can affect the speed/size of a wildfire.	-In plains, grass allows a wildfire to spread quickly. -Fire suppression methods caused vegetation to overgrow (more fuel) and allow wildfires to occur with	-People who live close to areas of more vegetation will be at higher risk to wildfires. -Not all wildfires are harmful, and some can help

		greater intensity. - Wildfires are beneficial because they kill disease and insects that eat vegetation. -More moisture in vegetation can reduce the intensity of a wildfire.	restore the environment. -Drought greatly increases the intensity of wildfires. -Warmer temperatures increase drought; increase in drought can increase fuel (dry vegetation).
Activity 4: Risky Business (Explore the hazards and risks caused by wildfires	Communities close to wildfire are at greater risk of damage. However, winds can spread the smoke to other neighboring communities.	-Knowing certain conditions (wind direction, speed, and humidity) can help determine which places are at higher risk. -Communities close to wildfires are at greater risk when they are located in the direction of the wind. -Types of risk include loss/damage of property, health issues, economic impact. -Fire lines and helitacks are ways in which we fight wildfires.	Communities in close proximity to more vegetation can be greatly impacted by wildfires. Increasing temperatures create suitable conditions (drought, dry vegetation) for more intense wildfires.
Activity 5: Wildfires in the Future (Investigate how climate change correlates to projected changes in wildfire frequency, intensity, risk, and impact)	-Warmer temperatures are expected to continue to rise.	- An increase in temperature increases drought and risk of more wildfires. -Vegetation has not evolved to sustain warmer weather.	

Evolution Module: Summary Table			
Activity	**What do we observe? What do we notice?**	**What is causing these patterns or observations? What does the data say?**	**How does this help us understand the evolution of living things?**
***Activity 1**: Variations and Adaptations*	There are variations in grass: short, medium, and large grass. Adult rabbits come in different sizes: small, medium, and large.	Both short and medium grasses grow best in lots of water. Large and medium grasses grow best in medium amounts of water. During droughts, large grasses can grow best but medium and short grasses do not. Small rabbits eat small grasses. Medium rabbits eat medium grasses. Large rabbits eat large grasses.	Environmental changes (weather) affect the amount of rain in the atmosphere. During rainy days/seasons, medium and large grasses grow well. During droughts small grasses disappear. The type of grasses available will affect the population of rabbits. Some rabbits will survive and reproduce but other rabbits will die.
***Activity 2**: Variation in Plants*	Plants with large leaves require shaded areas to grow. Plants with small leaves require sunny areas to grow.	Blue-flowered plants grow best in the sun because they have smaller leaves. Pink-flowered plants grow best in the shade because they have large leaves. Purple-flowered plants grow best in part sun/part shade because their leaves are medium-sized.	Different plants require different environments to grow, survive and reproduce. If plants cannot survive, they will die off.
***Activity 3**: Changes throughout Generations*	Plants can only live where the environment is right for them. Cycle of plants maintains survival. Parents die but seeds produce the offspring.	The blue-flowered plant grows best in sunny locations. The pink-flowered plant grows best in shady locations. The purple-flowered plant grows in semi-sunny	Plants of the same species can produce mutations that require different climates or conditions for the plant to survive.

		places.	
Activity 4*: Plant Adaptations*	Plant variations can have different leaf sizes. Different leaf sizes require different amounts of sunlight.	Small leaves need more sunlight; large leaves need more shade.	When plants survive and reproduce, their offspring can show different traits (variations) that allow the plant to survive in different environments.
Activity 5*: Changes in the Environment*	Environmental changes are caused naturally and by humans. Plants and animals can adapt to the environment when it changes slowly.	Plants are able to evolve and change over time when the environmental changes happen slowly. Different plants can have the same ancestor.	Changes that occur slowly in the environment allow living things to survive, reproduce and evolve. Changes that occur quickly can make organisms go extinct.
Activity 6*: Variation and Inheritance*	Same with plants with the same leaf size can grow in different places. Why?	Plants with the same leaves but different roots require a different amount of water. Therefore, they can live in different environments.	Even when plants have the same leaves, they may grow best in different amounts of water because of their roots.
Activity 7*: A Virtual Ecosystem*	An ecosystem is a place where different types of organisms can live together.	An ecosystem has resources available to other organisms.	When there's competition for food, some organisms survive and reproduce while others die. An ecosystem can become stressed when more organisms are competing for food resources.
Activity 8*: Natural Selection*	A dam is a physical barrier in an ecosystem.	This physical barrier can change the amount of food available for	Dams are quick changes to the environment, not all

		organisms in the different parts of the dam. This changes the population of organisms due to food availability.	organisms are able to survive in an ecosystem.
***Activity 9**: Predators and Prey*	In an ecosystem there are different organisms that feed on each other. The sun provides energy for plants to reproduce. Plants provide energy for rabbits. Rabbits provide energy for hawks. This is called the food chain.	Hawks eat rabbits. White rabbits camouflage themselves with the environment; therefore, its population remains high. Brown rabbits are easy to see; For this reason, the hawks feed on them easily and their population decreases. When the environment changes color, the opposite happens. If the population of hawks did not exist, the population of rabbits would increase and there would not be enough food to feed them because the competition for food increases.	All parts of an ecosystem are important and interrelated. Environmental conditions control which characteristics are most beneficial for organisms to survive and reproduce.