DEVELOPING CULTURALLY RESPONSIVE MATHEMATICS TEACHERS:

UNDERSTANDING EQUITY AND ACCESS IN MATH EDUCATION

A Doctoral Thesis Presented to the
Faculty of the College of Education
University of Houston

In Partial Fulfillment
of the Requirements for the Degree

Doctor of Education
In Professional Leadership

by

Lauren Hobbs

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Abstract

Background: Math is often thought to be one of the few objective, context-free areas of study. Yet, national and state assessment data repeatedly report disparities in mathematics achievement based on race/ethnicity and socioeconomic status. The perceived neutrality of mathematics education combined with persistent gaps in achievement between student groups can mislead educators to believe that some students are inherently incapable of achievement instead of questioning the inequities of students' educational experiences. Culturally Responsive Math Education (CRME) provides a framework through which teachers can critically examine their beliefs about students, their potential for learning mathematics, and the cultural and community-based experiences they bring into the classroom. **Purpose:** There are often significant cultural, racial, and social gaps between teachers and the diverse student populations they serve, as well as differences in their experiences with learning and using mathematics. Unfortunately, teacher preparation programs rarely provide the time and space needed for teachers to critically consider how their unique experiences contribute to their beliefs and assumptions about students from backgrounds different from their own. Guided by the CRME Framework, this action research study investigated the following questions: (1) How do teachers' sociocultural and mathematical backgrounds and experience influence their understanding and approach to equity and access in math education? and (2) How does professional development for CRME influence participants' understanding and approach to equitable and accessible math education within the context of a mid-sized rural school district? **Methods:** A qualitative case study design was used to investigate the experiences of nine elementary math teachers within a mid-sized rural school district who recently

participated in a five-week PD series designed to increase their understanding of CRME. Qualitative data were collected from participants' responses to pre- and post-PD open-ended questionnaires, math autobiographies, classroom observations, video recordings of PD sessions, and semi structured interviews, then transcribed, coded, and analyzed to identify key themes and patterns as they emerged for individuals, as well as the group as a whole. **Results:** Teachers' prior experiences as learners of mathematics, as well as sociocultural differences between teachers and their students, contributed to their beliefs about what counts as mathematical knowledge and who is capable of knowing it. Participants often used deficit-oriented language to describe their students' capabilities for learning mathematics and emphasized a procedural understanding of mathematics with low cognitive demand. However, after participating in a PD for CRME, teachers decreased use of deficit-oriented language while increasing resource-oriented language, placed a higher emphasis on the conceptual understanding of mathematics rather than procedural understanding, and demonstrated a new inclination towards mathematical discourse and student participation as opportunities for learning. **Conclusion:** A preference for procedural over conceptual understanding of mathematics combined with the notion that some students are mathematically deficient can hinder students' access to equitable learning opportunities. Findings suggest that elementary math teachers, particularly those working with traditionally underserved student populations, can benefit when given time and space to critically reflect and discuss their beliefs about their students and math education, impacting their understanding of equity and access within the math classroom.

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Chapter I

Introduction

> *"I believe that the absence of math literacy in urban and rural communities throughout this country is an issue as urgent as the lack of registered Black voters in Mississippi was in 1961" (Moses & Cobb, 2001a, p. 5).*

While conducting research for this study, participants and I discussed Bob Moses, 1960s Civil Rights Activist and founder of The Algebra Project, a national nonprofit organization created to "close the gap between universal free public education and universal completion of a college preparatory math sequence in high school (Moses & Cobb, 2001a, p. 93). The organization was built upon Moses' belief that math literacy is necessary to achieve full citizenship and economic success. I had high hopes that reading about and discussing the Algebra Project would provide a new perspective on math education as a gatekeeper to postsecondary opportunities and success, when one participant commented,

> I'm sorry, but I just don't think everyone is college material, I just don't! Just because you don't have "math literacy," you don't have some kind of safety net, they are basically saying you are going to end up in the same position as the sharecroppers. So, what? I think there are other reasons to learn math. It doesn't have to be just to get a great job, because we need people to flip hamburgers, too. We need that. There's a demand for people without college degrees right now.

As a math instructional coach and former high school math teacher who strongly believes that all students are capable of mathematical success, I was stunned to hear an experienced elementary math educator speak about her students' futures with such

hopelessness. Unfortunately, deficit-based language that attempts to define the academic potential of marginalized student groups is not uncommon in schools serving our most vulnerable student populations (Howard & Rodriguez- Minkoff, 2017).

Background of the Study

Math literacy, the understanding of and ability to use quantitative information (Moses & Cobb, 2001a), is more important now than ever before, as the job markets in STEM-related fields are growing rapidly in response to technological advances. Moses and Cobb (2001b) agree, "In an era where the 'knowledge worker' is replacing the industrial worker, illiteracy in math must now be considered as unacceptable as illiteracy in reading and writing" (p. 6). Reports released by the U.S. Department of Commerce confirm that U.S. employment in STEM-related fields grew at a rate of 24.4% versus just 4.0% growth in non-STEM fields, and projected STEM-related fields would continue to grow at a rate of 24.4%, as opposed to 6.4% in non-STEM fields (Noonan, 2017). Becoming mathematically literate before high school graduation provides students with the necessary foundation for future achievement in postsecondary the courses required to obtain these jobs of the future, and eventually, economic success.

Yet, repeated analyses of student data at both state and national levels indicate that some student groups, defined by race, ethnicity, class, socioeconomic status, and/or language consistently outperform their peers on achievement tests, experience higher graduation rates, and enroll in university courses at higher rates (College Board, 2017; National Center for Education Statistics, 2017). The term *achievement gap* is often used in public school settings to describe the perceived disparity in academic success between student populations (Milner, 2013). Achievement gap rhetoric is not new, however, as it

can be traced back to at least 1966 within the Equality of Educational Opportunity Report commissioned by the U.S. Department of Education (Coleman, 1966) that heavily relied on educational outputs to measure school effectiveness. The report claims that out-of-school factors, such as poverty, community values, and parents' educational attainment are predictive of student achievement, as "schools bring little to bear on a child's achievement that is independent of his background and general social context" (p. 325).

More recent efforts in education reform, such as the No Child Left Behind Act (NCLB) of 2001 and the current Every Student Succeeds Act (ESSA), are still attempting to close the achievement gap by focusing on student performance on standardized tests.

Table 1

U.S. Graduates Meeting ACT Math College-Readiness Benchmark, 2009 – 2017

Class	African American	American Indian	Asian American	Hispanic	Pacific Islander	White
2017	13%	16%	70%	26%	26%	51%
2015	14%	20%	69%	29%	30%	52%
2013	14%	22%	71%	30%	37%	53%
2011	14%	25%	71%	30%	36%	54%
2009	12%	39%	65%	27%	N/A	50%

Table 1 illustrates the national percentage of high school graduates prepared for college-level math coursework by race/ethnicity between 2009 and 2017 (ACT, 2017, 2015, 2013, 2011, 2009). The data presented each year consistently reflects the same achievement gap pattern – African American students are presented as the least college-ready group, followed by the American Indian, Hispanic, and Pacific Islander student groups. Asian American and White student groups are consistently presented as the most prepared for advanced coursework, as they have the highest percentage of students

meeting the college readiness benchmark in mathematics every year. The most recent gap presented by Table 1 reveals an astounding 57% gap between the African American and Asian American student groups.

However, a narrow focus on achievement gaps without consideration for *why* some groups outperform others can lead teachers to hold deficit views of student abilities and low expectations for achievement based exclusively on their interpretations of these scores, often before they even meet these students (Milner, 2012b). This approach to assessment data does not consider the inequitable educational opportunities afforded to marginalized student groups within the public education system (Gutiérrez, 2008; Milner 2012b). The phrase *opportunity gap* is used by stakeholders wanting to shift the focus from achievement gaps and static test scores to the inequitable access to educational inputs, such as rigorous instruction, experienced teachers, or high-quality curricular resources (Flores, 2007; Milner, 2012b). Ladson-Billings (2006) pushes the argument a step further, suggesting that educational disparities are more akin to an education *debt* that has continued to accumulate over time than simply a gap in achievement.

Mathematics classes, specifically Algebra classes, are often referred to as gatekeeper courses, as the enrollment and subsequent completion of such courses separates "smart" students, perceived to be better at math, onto an accelerated track towards advancement and achievement throughout high school and college (Buckley, 2010). Stinson (2004) elaborates,

> In the United States, school mathematics evolved from a discipline in "crisis" into one that would provide the means of "sorting" students. As student enrollment in public schools increased, the opportunity to enroll in advanced mathematics

> courses (the key) was limited because some students were characterized as "incapable." Female students, poor students, and students of color were offered a limited access to quality advanced mathematics education. (p. 12)

The belief that students are inherently "good" or "bad" at math contributes to the notion that marginalized groups are deficient in mathematical ability and incapable of mathematical success (Jett, 2013). As deficit ideologies persist, privileged student groups – specifically white males from higher socioeconomic backgrounds – are given greater opportunities and exposure to rigorous content and instruction, leading to even higher standardized test scores, more postsecondary options, and a widening achievement gap (Buckley, 2010).

Inequitable access to mathematics education means inequitable access to economic success and freedom. Cobb and Hodge (2010) define equity work in math education as addressing three areas of concern – (a) access to opportunities that enable students to participate in out-of-school mathematics in significant ways, (b) access to opportunities for enrollment and success in advanced, college-tracked mathematics courses, and (c) access to opportunities that cultivate a positive identity as a learner of mathematics. Unfortunately, many educators still believe math education to be objective and context-free, consisting of algorithms and computations, with little consideration to their use outside of the classroom (Battey, 2013; Ukpokodu, 2011). This perspective can significantly impact the complexity and rigor of the mathematical tasks a teacher plans for her students. Grant, Crompton, and Ford (2015) agree –

> The cognitive level of the task affords different types of teaching and learning opportunities. High-level tasks that require students to engage mathematically, to

> seek connections to other mathematical ideas, and to prove their approaches, require teachers to facilitate learning differently than low-demand tasks that only require students to recall memorized facts that teachers, in turn, validate. (p. 90)

As educators, it is our job to ensure that *all* students have access to high-quality instruction and the opportunity to graduate mathematically literate, able to apply and interpret mathematics across contexts.

Statement of the Problem

Despite the variety and availability of data and research, inequities still persist in K – 12 math classrooms. Standardized test scores continue to purport an "achievement gap" between students from low-income and high-income households, as well as between racial/ethnic groups (ACT, 2017; College Board, 2017). Numerous studies have examined the achievement gap (Gaddis & Lauen, 2014; Strand, 2014; White et al., 2016), the opportunity gap (Goldenberg, 2014; Milner, 2012b; Wilhelm, Munter, & Jackson, 2017), as well as pedagogical approaches to address the problem (Bonner, 2014; Jackson & Jong, 2017; Ladson-Billings, 1995a; Ladson-Billings 2014). Yet, the problem persists.

There is a small, yet growing, research base that examines professional development (PD) to support math teachers' development of effective dispositions and practices to make content more accessible to diverse student populations (Bonner, 2014; Turner et al., 2012; Wager & Foote, 2013). Unfortunately, many teacher preparation programs leave their students ill-equipped to address the hidden inequities within their practice (Hayes & Juarez, 2012; Williams, Edwards, Kuhel, & Lim, 2016). Approaching education through a culturally responsive lens can help teachers to capitalize on students' background knowledge in an effort to bridge meaningful, real-world connections

(Harding-DeKam, 2014; Hinnant-Crawford, 2016; Rubel, 2017; Turner et al, 2012). Math teachers tend to have an overly objective view of their subject matter (Timmons-Brown and Warner, 2016) and find it particularly difficult to understand how cultural responsiveness can work within the context of their classroom (Bonner, 2009). Gorski (2016b) warns,

> If we only prepare future educators to be aware of outcome disparities or to think of achievement gaps solely in terms of test score disparities, 'dropout' rates, or other symptoms of economic injustice, and not as the opportunity gaps that they actually are, we may be inviting them, even if unintentionally, to slide into a deficit or grit view. If we equip them with practical instructional strategies but fail to facilitate the difficult ideological work necessary to become responsive to structural barriers within their spheres of influence (even if they cannot eliminate those inequities altogether) we become facilitators of deficit ideology. (p. 384)

This study intends to supplement the growing body of literature concerning culturally responsive mathematics PD frameworks created to inform teachers' dispositions towards, and practices to better serve, diverse student populations.

Theoretical Framework

Participatory action research. Committed to the transformative social justice agenda, participatory action research provides a collaborative framework for practitioners to transform their practice in an effort to bring about meaningful social change within their community (Brydon-Miller & Maguire, 2009). This type of research is "associated with critical theory in that it is action research committed to social transformation through active involvement of marginalized or disfranchised groups" (Glesne, 2016, p.

25). Brydon-Miller & Maguire (2009) name three key principles of participative action research: research as an important form of political engagement, critical evaluation of systems that precipitate power and privilege, and an emphasis on collaborative relationships as a framework for effective practice (p. 83). The present study reflects these three principles, as it is designed to promote collaboration and collective reflection amongst math teachers as they critically examine the equity and accessibility of mathematics education and their own instruction.

Culturally responsive mathematics education. All students need regular opportunities to engage with high-quality math instruction and support, as well as to experience mathematical success in an environment with high expectations (NCTM, 2014). The theoretical foundation of this study was developed to help teachers meet this need for diverse student populations. This framework was informed by previous research on cultural responsiveness in mathematics education, as well as best practices in professional development.

Culturally Responsive Education (CRE) is an umbrella term used to describe the critical ideologies, dispositions, and practices associated with providing an equitable and accessible education for diverse student populations (Dover, 2013). Previous research has established cultural responsiveness as a viable way for schools within diverse communities to provide more accessible educational opportunities for their students, while also decreasing both economic and democratic inequities (Aguirre & del Rosario Zavala, 2013; Bonner, 2014; Grant et al., 2017; Harding-DeKam, 2014, Hinnant-Crawford; 2016; Strutchens et al., 2012). Aronson and Laughter (2016) explicate CRE by distinguishing two essential strands of education – *pedagogy*, the dispositions and beliefs

teachers bring with them to into the classroom, and *teaching*, their actual instructional practice. Within the context of CRE, these two strands embody Ladson-Billings' (1995a) Culturally Relevant Pedagogy and Gay's (2002) Culturally Responsive Teaching.

The first strand, Culturally Relevant Pedagogy (CRP), was based on Ladson-Billings' (1995a) observations of effective educators known for their success with traditionally underserved students. She noticed very few patterns in their instructional practice but did identify three commonalities in their philosophies of education – (a) all students must experience academic achievement, (b) students must maintain, or develop, cultural competence, and (c) students must develop critical consciousness through which they can challenge the status quo. The second strand, Culturally Responsive Teaching (CRT), uses "the cultural characteristics, experiences, and perspectives of ethnically diverse students as conduits for teaching them more effectively" (Gay, 2002, p. 106). CRT includes five essential practices – (a) develop a knowledge base about cultural diversity, (b) include ethnically and culturally diverse content in curriculum, (c) demonstrate caring and build a learning community within the classroom, (d) communicate effectively with ethnically diverse students, and (e) respond to diversity in the delivery of instruction. (Gay, 2002, p. 106). Together, these pedagogical beliefs and teaching practices reflect the values and assumptions of Culturally Responsive Education.

Similar to Aronson and Laughter's (2016) identification of culturally responsive pedagogy and practice to define CRE, this study identifies a framework for Culturally Responsive *Mathematics* Education (CRME) based Culturally Relevant Mathematics Pedagogy (Rubel and Chu, 2012) and Culturally Responsive Mathematics Teaching (TEACH MATH, 2012). Both strands are essential to the model of CRME illustrated in

Figure 1, as the pedagogical side describes culturally responsive dispositions, values, and attitudes, and the teaching side describes the methods, practice, and actions required of culturally responsive mathematics teachers.

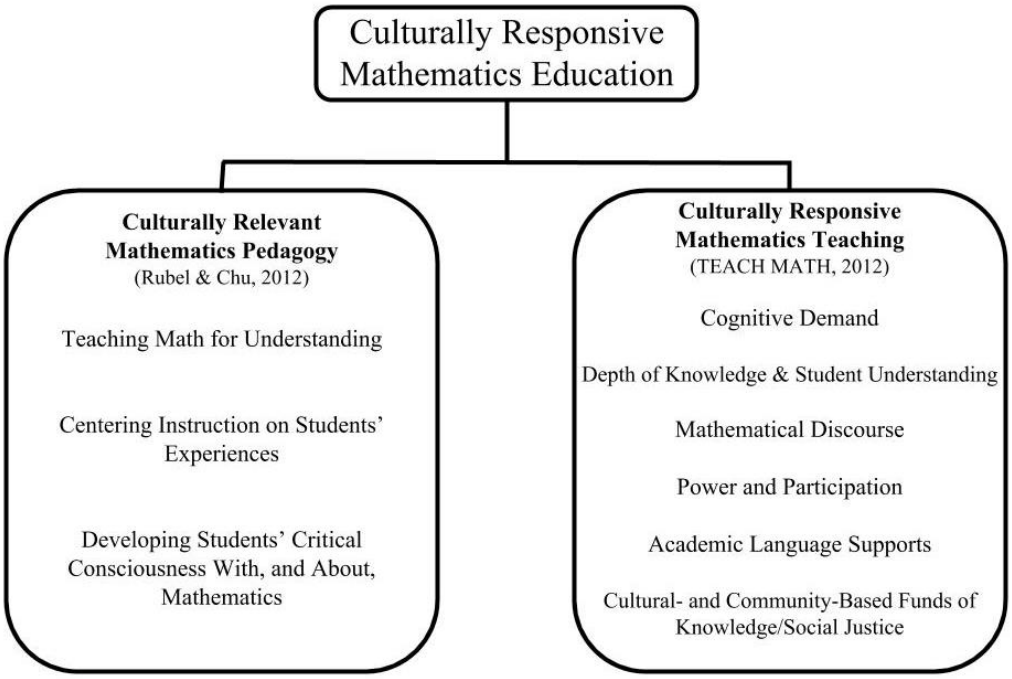

Figure 1. Culturally Responsive Mathematics Education Framework

Culturally Responsive Mathematics Pedagogy (CRMP) places students' cultural and community-based experiences at the center of mathematics teaching and learning (Rubel & Chu, 2012). Grounded in Ladson-Billings' three elements of Culturally Relevant Pedagogy, CRMP includes three dimensions – (a) teaching mathematics for understanding, (b) centering instruction on students' experiences, and (c) developing students' critical consciousness with, and about, mathematics (2012). CRMP's core dimension, *teaching mathematics for understanding*, highlights the importance of making connections between procedural and conceptual mathematics, while deemphasizing algorithmic memorization and prescriptive procedures. Teaching for understanding also

means that teachers are able to situate new learning within familiar sociocultural contexts to aid in mathematical comprehension through problem solving. The second dimension, *centering instruction on students' experiences*, requires teachers to not only recognize students' background and experiences, but utilize them by purposefully integrating relatable contexts into the planning an delivery of math instruction. Centering instruction on students' experiences makes the content more accessible, as students are able to see the usefulness of what they are learning as active participants in the learning process. The final dimension asserts that teachers *develop students' critical consciousness with and about mathematics*. By developing critical consciousness *with* mathematics in the classroom, students are encouraged to address social issues and inequalities as an application of their learning. Developing critical consciousness *about* mathematics requires students to critically examine mathematics itself, including what it means to "know" math, who is capable of knowing it, and the educational experiences of marginalized student groups.

Although not explicitly linked prior to this study, the Culturally Responsive Mathematics Teaching(CRMT) Lesson Analysis Tool (TEACH MATH, 2012) aligns closely with CRMP's beliefs about mathematics education. This tool was created in pursuit of two goals – (a) the development of students' mathematics thinking and (b) equity within the mathematics classroom (Aguirre, 2012). The CRMT- Lesson Analysis Tool identifies six elements of culturally responsive mathematics teaching: Cognitive Demand, Depth of Student Knowledge and Understanding, Mathematics Discourse, Power and Participation, Academic Language Support, and Cultural- and Community-Based Funds of Knowledge/Social Justice.

The first three dimensions, Cognitive Demand, Depth of Student Knowledge and Understanding, and Mathematics Discourse, focus on the development of students' mathematical thinking (Aguirre, 2012). *Cognitively Demanding* tasks require students to understand the "why" behind the mathematics as teachers "elicit student thinking, analysis and reasoning" (p. 2). Providing all students with opportunities to learn from tasks with a high cognitive demand increases access to high-quality, challenging mathematics instruction, as opposed to simply practicing or reciting memorized facts. When students are engaged in cognitively demanding tasks, they are more able to develop a deep mathematical understanding rather than a skills-based, superficial understanding (2012). Therefore, *Depth of Knowledge and Student Understanding*, the second dimension, makes understanding visible by asking students to explain and justify the connections they make between mathematical concepts and procedures. The third dimension, *Mathematical Discourse,* creates opportunities for students to discuss mathematics with their peers in collaborative and meaningful ways, such as "debate math ideas/solution strategies, use math terminology, develop explanations, communicate reasoning, and/or make generalizations" (TEACH MATH, 2012, p. 1).

The final three dimensions – Power and Participation, Academic Language Support, and Cultural- and Community-Based Funds of Knowledge/Social Justice – were included to promote equity in the math classroom (Aguirre, 2012). The *Power and Participation* dimension emphasizes that "all mathematical contributions are valued and respected" (TEACH MATH, 2012, p. 4). Status within the classroom is minimized, as mathematical knowledge and authority is shared between the teacher and students. *Academic Language Support* within the CRMT Lesson Analysis Tool references English

Language Learners specifically, providing scaffolds to support the development of academic language within each subject area. Finally, *Cultural- and Community-Based Funds of Knowledge* highlights the role of students' backgrounds and experiences in making math curriculum accessible by presenting it within a familiar context. By engaging in community activities, teachers have the opportunity to learn about the community's culture and values and build strong relationships, helping to strengthen the level of cultural competence they bring into the classroom. The *Social Justice* aspect of this dimension encourages the "deliberate and continuous used of mathematics as an analytical tool to understand an issue/context" (p. 5) as mathematics is used to empower students to challenge the current status quo.

Purpose of the Study

The first purpose of this study was to understand the influence of teachers' mathematical and sociocultural backgrounds on their current understanding and approach to equity and access in math education. According to Gay (2013), "Teachers tend to use instructional examples culled from their own personal experiences and those of people and communities similar to themselves. But ethnically and culturally diverse students and teachers often do not have these reference points in common" (p. 67). Numerous studies have noted the existence of cultural and racial gaps between teachers and their students (Battey, 2013; Diggles, 2014; Gay, 2013; Goldenberg, 2014). Recent data from the National Center for Education Statistics (2017), shown in Table 2, confirm that demographic differences between students and teachers persist. This can lead to a significant gap in lived experiences, leaving teachers unaware of the systemic barriers to equity in education and oblivious to their students' unique circumstances (Wager &

Foote, 2013). Teachers' ability to understand and reflect on their instructional practices in terms of equity and access is imperative to the education of students with backgrounds different from their own (Durden & Truscott, 2013).

Table 2

National Demographics of Public School Students and Teachers by Race/Ethnicity

Race/ Ethnicity	Students	Teachers
White	49.5%	80.1%
African American	15.5%	6.7%
Hispanic	25.4%	8.8%
Asian/Pacific Islander	5.3%	2.5%
American Indian/Alaska Native	1.0%	0.5%
Two or More Races	3.2%	1.4%

The second purpose of this study was to describe how professional development for CRME influenced teachers' understanding and approach to equitable and accessible math instruction. Few teacher preparation programs have been found to prioritize multicultural education or cultural responsiveness when educating pre-service teachers (Hayes & Juarez, 2012). As a result, new teachers often begin their careers with limited understanding of the needs of diverse student populations, and it becomes the responsibility of district and school-based instructional leaders to address this deficiency for the sake of their students. It is my hope that this research will positively contribute to the small, but growing, body of literature centered on professional development and equity work in math education (Aguirre & del Rosario Zavala, 2013; Battey & Franke, 2015; Rubel, 2017; Wager & Foote, 2013).

Research Questions

The following research questions guided this study:

1. How do teachers' sociocultural and mathematical backgrounds and experiences influence their understanding and approach to equity and access in math education?
2. How does professional development for CRME influence participants' understanding and approach to equitable and accessible math education?

Statement of Positionality

Engaging in equity work requires researchers to critically reflect on their own backgrounds and experiences as they relate to inherent privilege and bias. Aguirre et al. (2017) state,

> The choices we make about our research, whether epistemological, methodological, theoretical, and so on, are shaped by who we are, what our experiences have been, what we value, and the ideologies we (knowingly or not) ascribe to. By recognizing that these choices are shaped by our lived experiences and identities, MERs [math education researchers] can reflect on unintentional and inequitable practices in all aspects of our research. (p. 126)

Attending to my own sociocultural history, values, and ideologies was a much more daunting task than I had anticipated. Therefore, my statement of positionality was informed by Milner's (2007) framework of researcher racial and cultural positionality which includes researching the self, researching the self in relation to others, engaged reflection and representation, and shifting from self to system.

To start, I am a white female who was raised in a middle-class, suburban community for most of my childhood. My parents were both hard-working, college-educated engineers, and they set the expectation very early that I would also one day go to college. As a child, I thought my experiences and upbringing were the same as everyone else's, and that all high school graduates knew that they could and would go to college. While my parents' desire for me to get a college education was not unique, I recognize that many people do not have the advantages I was born into that made this path more accessible to me. At the time, I assumed my experiences was the norm for all families, and this was how parents universally demonstrated that they cared about their child's education. While I do know that my parents cared about my education, I now also recognize that my inherent privilege has removed multiple barriers throughout my lifetime that others still have to face. My reality is *not* universal.

This research is not just about equity in education, but equity in *mathematics* education, a field usually considered race-neutral and context-free (Battey, 2013; Rubel, 2017). According to Foote and Bartell (2011), "Research in mathematics education requires attention to the complexities of teaching mathematics, including how teaching mathematics is influenced by broader social, economic, and political structures, and how one's researcher positionality informs or constrains what one sees and concludes" (p. 48). Therefore, I must also acknowledge my positionality as a mathematics teacher and learner, instructional coach, and researcher.

As a young learner of mathematics in elementary school, I remember quickly and proudly reciting my multiplication facts as we played competitive games in class to see who was the fastest. I was almost always faster than the rest of my classmates, which

made me feel smart and confident. Unfortunately, this skill did not support the conceptual foundation needed for complex algebraic thinking and number manipulation, and I found it very difficult to think abstractly when I took 8th Grade Algebra. It was not until I became a high school Algebra II teacher that I truly understood the powerful connections between mathematical concepts, and I realized the fact that there is never only one way to approach a problem.

As an instructional coach, I do not evaluate any of my teachers, but there is a hierarchical nature to our relationship. While I do my best to maintain positive and collaborative relationships, my role leans more towards being the expert while my teachers are supposed to learn from what I tell and show them. My personal values and beliefs about mathematics affect this process of teaching and learning, which may or may not always be shared by my teachers. For instance, I believe that *all* students are capable of learning math at high levels, and it is up to us as both educators and public servants to consider our *students*' perspectives and experiences when making mathematical connections, building upon the valuable knowledge they have when they walk into our classrooms – mathematically-based or not. But what counts as learning mathematics is a point of disagreement within the math education community between those who believe math is an inherent or learned skills, as well as between those who emphasize conceptual understanding and those who emphasize computational skill and memorization.

According to Koestler (2012), "Teacher educators (and education researchers) have a moral and ethical responsibility to examine and address issues of equity and social justice in their work with teachers in order to support teachers in creating more equitable and just classrooms" (p. 91). I believe that the purpose of learning mathematics is twofold

– first, to help students understand and question the world around them in a thoughtful and productive way, and second, to increase students' access to future postsecondary opportunities. As an instructional leader and influencer, I see it as my responsibility to help teachers of mathematics understand that mathematical understanding is not an innate ability that a privileged few have and others do not. Just as Delpit (2012) asked, "How can we look at a small bundle of profound potential and see only a number describing inadequacy? Why do we punish our children with our inability to teach them?" (p. 12).

Overview of Methodology

This action research utilized a case study design as it sought to provide detailed and descriptive insight into participants' experiences throughout the PD series and identify any changes in their understanding and approach to equitable mathematics instruction. This study took place in a midsized rural school district in which I was employed as a mathematics instructional coach. This role allowed me to facilitate PD activities to teach participants about CRME as part of my regular professional responsibilities. Nine elementary mathematics teachers volunteered as research participants to engage in discussions and reflections concerning CRME, their previous sociocultural and mathematical experiences, articles, videos, and activities throughout the study.

According to Creswell (2013), "A hallmark of a good qualitative case study is that it presents an in-depth understanding of the case" (p. 98). Multiple forms of qualitative data were collected and analyzed to reach an in-depth understanding, including video recordings from PD sessions, participants' math autobiographies, semi structured interviews, classroom observations, researcher's field notes, and participants' responses

to open-ended pre- and post-PD questionnaires. Data was collected and analyzed simultaneously and organized into a coding scheme to reveal key themes and patterns as they emerged for individual participants, as well as the group as a whole.

Significance of the Study

> *The question remains: How do the people at the bottom get into the mix? In the 1960s, in Mississippi, it was the sharecroppers. In our time, across the country, it is Black, Latino, and poor white students who are trapped at the bottom with prisons as their plantations. Are we going to have a society where only a small group of people are prepared for the future, where there's a huge knowledge gap? How does such a society stabilize itself?* (Moses & Cobb, 2001a, p. 12)

Equity-focused research in mathematics education is of the utmost importance right now, as math's gatekeeper status continues to deny access to marginalized student populations pursuing economic success and freedom. The demographic differences found between many mathematics educators and their students raise questions about "how a system can change if the workforce charged with the transformation does not reflect the communities it serves, or is unaware of the academic and social needs and resources of all students" (National Council of Supervisors of Mathematics & TODOS: Mathematics for ALL, 2016, p. 3).

In October 2017, equity mathematics education scholar Rochelle Gutiérrez received notable attention for bringing attention to the politics of math education in a polarizing chapter she wrote titled *Political Conocimiento for Teaching Mathematics: Why Teachers Need It and How to Develop It*. In the chapter, Gutiérrez (2017a) argues that teachers need as much training in how to handle the politics of teaching as they get in

lesson planning, assessment writing, instructional strategies, classroom management, and other necessary components of teacher education. They need time and space to consider how their "values, morals, and judgments all come into play, and these are the heart of politics" (p. 17). Without it, math continues to keep its gatekeeper status and ability to grant access to eventual economic success and freedom.

After learning of Gutiérrez's stance on equity in math education, Fox News, along with various other conservative news outlets, publicly attacked and criticized the suggestion that math teachers need political knowledge and awareness, arguing in favor of math as universal and colorblind (Gutiérrez, 2017b). Despite public support from numerous reputable organizations, including the National Council of Teachers of Mathematics (Larson, 2017) and the Association of Mathematics Teacher Educators (2017), equity mathematics education research is still under fire. However, the disparities in mathematics achievement between racial and social student groups are too real and important to leave unaddressed.

Jett (2012)'s call for scholars to work towards a more equitable approach to mathematics education summarizes the significance of this study: "The time is now for us not to simply engage in dialogue about equity work, but to act conscientiously in our respective spaces to empower others" (p. 28). This action research is intended to help leaders at the school and district levels better understand that as our schools become increasingly diverse, the need to provide professional learning opportunities for teachers to ensure all students have access to equitable and rigorous mathematics instruction also increases. School leaders, administrators, and instructional coaches can help teachers understand the role of equity and Culturally Responsive Mathematics Education by

providing high-quality PD to inform meaningful changes to deficit mindsets and classroom instruction, ensuring *all* students equitable access to rigorous and relevant mathematical content.

Limitations

The first limitation of this study was the use of volunteers as participants, excluding a population of teachers who were not interested in this type of PD or research and therefore less likely to understand the need for equity in math education. Culturally responsive practices and mindsets have yet to fully permeate the field of mathematics education, leaving many of its teachers with a "not my job, not my problem" mentality (Hudley & Mallinson, 2016). While I believe that professional learning to support math teachers become more culturally responsive is beneficial, not all educators would be as open to change if they were required to participate. Teachers who would have been resistant and unwilling to critically reflect on their practice through a culturally responsive lens would likely not benefit themselves or the district by participating in this study.

A second limitation is the inability to generalize the findings from action research due to the contextual nature of the problem it attempts to address (Mertler, 2016). This study was created to analyze and respond to the details of a specific problem within a specific school district, not necessarily to uncover generalizable truths applicable outside of the unique setting. The goal of action research "is not to generalize findings to other settings but instead to have a clear and in-depth understanding of this particular setting" (Mertler, 2016, p. 141). Therefore, conclusions are reflective of the specific context of the study and results may not be generalizable to a larger population.

A third limitation is the potential of my own bias influencing the validity of the research data (Mertler, 2016). Despite making every effort to analyze and present data in a neutral way, I do believe that mathematics teachers need to be more reflective and purposeful when considering the role of students' culture, equity, and access in their instruction. These opinions could have potentially influenced my line of questioning, interpretation of observations, and/or data analysis.

Organization of the Study

This dissertation is organized into five chapters. Chapter 1 has established the background context, statement of the problem, and purpose of this study. It also presented the two research questions and theoretical framework that guided the research. Chapter 2 provides an overview of major themes identified in the literature related to the research topic: the achievement gap and deficit ideology, Culturally Responsive Education/Culturally Responsive Mathematics, and building teacher capacity for equitable mathematics teaching. Chapter 3 describes the research design and methodology used to carry out this study. Research methods, the setting and participants, and procedures for data collection and analysis are explained in greater detail. Chapter 4 presents the data and findings in regards to participants' sociocultural and mathematical backgrounds, as well as their experiences within the PD series, for each research question. Finally, Chapter 5 will expand upon the research findings, providing implications for the CRME Framework, district leadership, and suggestions for future research.

Definitions of Key Terms

The following terms and knowledge of their meaning are essential to understanding this research:

Access: Having full opportunity to engage with cognitively demanding mathematics in school and succeed in advanced gatekeeper courses throughout high school and college, resulting in greater postsecondary educational and career options, as well as higher levels of economic success

Critical Reflection: A process of reasoning and self-assessment to understand and critique one's own worldview and recognize how it shapes one's perspectives and beliefs about those from backgrounds different from our own.

Culture: A set of dynamic and locally enacted practices grounded in shifting social networks and relationships through which people identify themselves and others (Cobb & Hodge, 2010)

Culturally Responsive Mathematics Education (CRME): An approach to equitable and accessible mathematics education that builds upon the knowledge that students bring into the classroom, including mathematical, cultural, and/or community-based knowledge, to enact social change within and through the math classroom

Equity: Ensuring all students have (a) access to opportunities that enable students to participate in out-of-school mathematics in significant ways, (b) access to opportunities for enrollment and success in advanced, college-tracked mathematics courses, and (c) access to opportunities to cultivate a positive identity as a learner of mathematics (Cobb & Hodge, 2010)

Professional Development: Ongoing, sustained activities for providing educators with the knowledge and skills necessary to enable all students to experience success (Every Student Succeeds Act, 2015).

Sociocultural Perspective: Understanding the social and environmental contexts as integral to the learning process, as knowledge is socially constructed.

Chapter II

Literature Review

This purpose of this study was to understand the influence of elementary math teachers' sociocultural and mathematical backgrounds on their understanding and approach to equity and access in math education, as well as to describe ways in which PD for CRME influenced their understanding and use of equitable teaching practice. This chapter presents an overview of three themes within relevant literature to provide context and background for the present study, which I describe below.

The first theme contains literature related to the achievement gap and deficit ideology, making a distinction between research based on test scores alone and those based on equitable opportunities to learn. The achievement gap itself, a socially constructed notion, does not provide any objective or irrefutable conclusions about different groups of children: "What these so-called gaps do highlight are the adverse conditions under which some children are often forced to learn, the privileged conditions afforded to others, and how forces like racism are used to position students in a racial hierarchy" (Martin, 2009, p. 300). This portion of the review speaks to the systemic inequities in student educational experiences and opportunities that continue to allow for the disparity in student outcomes.

The next theme addressed in this review centers on cultural responsiveness as a path towards equity by addressing the inequitable learning opportunities afforded to marginalized student populations. Addressing the barriers created by gatekeeper mathematics is central to these studies, as culturally responsive educators acknowledge their existence within the education system and purposefully use students' background

knowledge and out-of-school experiences as bridges to conceptual understanding (Aronson & Laughter, 2016). An overview of the historical development of CRE will be provided, as well as its role specifically in mathematics education, followed by the acknowledgement of documented difficulties and cautions for CRME implementation.

The final theme reviews existing PD models and frameworks used to provide educators with professional learning experiences to support the planning and delivery of culturally responsive instruction. Identifying effective modes of teacher education that encourage implementation of culturally responsive practices are critical to address equity and access in math education, as "equitable mathematics practices do not develop overnight; teachers need the opportunity to learn what equitable practices look like in theory and closely examine their own practice to identify sites for change" (Wager, 2014, p. 314). Literature concerning the development of culturally responsive mathematics educators includes teacher pre-service programs, PD for practicing teachers, ongoing coaching to sustain changes in teacher practice, and existing PD models and frameworks for CRME. This literature review will conclude with calls for future research from some of the most recent studies in equitable mathematics and professional development for culturally responsive mathematics educators.

The Achievement Gap and Deficit Ideology

The term "achievement gap" is often used when describing the perceived disparity in academic achievement between student groups based on race/ethnicity, socioeconomic status, and/or language (Milner, 2013). In the current era of high-stakes testing and school accountability, test scores obtained from standardized state assessments often serve as a primary data source in order to determine whether or not

schools are effective and students are successful (Reardon, 2013). Underperforming schools with consistently low-performing students then prescribe curricular and pedagogical mandates in an attempt to standardize the student experience instead of responding to individual student needs (Sleeter, 2012). However, this course of action contradicts current research in education, such as the research conducted by Darling-Hammond, Friedlaender, and Snyder (2014) that found that the schools who were most successful with typically underserved students were more likely to "keep their eye on the goal of learning rather than on a pacing guide or test preparation" (p. 10).

Though numerous studies have identified achievement gaps after disaggregating data from standardized assessments data into groups by race and income (Lee, 2012; Reardon, 2013; Reiegle-Crumb & Grodsky, 2010; Strand, 2014), research conducted solely for the purpose of identifying achievement gaps risk implies that some student groups are inherently less capable than others (Flores, 2007). "Achievement gap" rhetoric reinforces negative stereotypes that some student groups, usually White upper- to middle-class students, are inherently more capable of success, while all other groups are naturally deficient and should work towards achieving comparable levels of success (Jett, 2013; Martin, 2013). For example, Gaddis and Lauen (2014) concluded that differences in school composition, specifically the percentage of affluent students vs. students living in poverty, plays a significant role in a school's ability to tackle racial inequality, yet do not suggest potential solutions to the problem.

Milner (2013) points to numerous consequences of a narrow focus on achievement gaps. First, it encourages the comparison of racial/ethnic groups without consideration of what causes disparities and differences in achievement. Second, it

implies that White students are intellectually and academically superior, encouraging a deficit perspective of minority student shortcomings. Lastly, the focus remains solely on the successes and failures of particular groups of students instead of the inequitable systems and structures that led to the gap to begin with.

Though achievement gap analysis can highlight areas in need of new policies or practice, critics have argued that a static focus on the existence of a gap is not enough (Gutiérrez, 2008). Martin (2009) agreed, "Most studies of differential outcomes in mathematics education begin and end their examination of race with static categories and group labels that are used for the sole purpose of disaggregating data" (p. 313). The term "opportunity gap" is used to shift the focus from disparities in achievement to the inequities of students' educational experiences and opportunities (inputs), resulting in a very different and proactive diagnosis (Flores, 2007). From this perspective, disparities in student achievement become a symptom of the larger equity problem.

Deficit beliefs and teacher expectations. The effects of teacher expectations on student performance is well documented in the literature (Garcia & Chun, 2016; Hinnant-Crawford, 2016; Jackson, 2013; Pitre, 2014). Teachers' deficit ideology and implicit biases against particular groups of students can "lead to complacency, acceptance of failure, and low teacher expectations" (Pitre, 2014, p. 214). This was the case when Foote et al. (2013) studied prospective teachers' orientations towards students' family and community – while participants recognized the importance of communication with parents and connections to the community, they often held deficit beliefs, interpreting parents' actions as uncaring and devaluing education instead of considering alternate for behaviors that were inconsistent with their own upbringing.

A lack of exposure to high expectations for performance is an inequitable barrier to student achievement (Flores 2007). Garcia and Chun (2016) investigated the effects of teacher expectations and culturally responsive teaching on academic outcomes of Latino middle school students using students' perceptions of teacher expectations, academic self-efficacy, and grades. They concluded that the Latino students' perceptions of teacher expectations affected their academic performance and self-efficacy, indicating the need for teachers to explicitly communicate high expectations for all students.

Wilhelm et al. (2017) studied the relationship between teachers' explanations for student difficulty in mathematics and the quality of learning opportunities they afforded their students. The authors were able to distinguish between two types of explanations from teachers – productive explanations that attributed student difficulties to educational opportunities, and unproductive explanations that attributed student difficulties to factors they felt were outside of their control, such as inherent ability, behavior, home life, or motivation level. They conclude that teachers' productive or unproductive beliefs about the source of students' struggles were, in fact, related to the quality of learning opportunities they provided for their students. Additionally, "the strength of this relation depends on the composition of students in the classroom with respect to race, ethnicity, and/or language status" (p. 362).

Peterson, Rubie-Davies, Osborne, and Sibley (2016) studied the effects of elementary teachers' explicit expectations and implicit attitudes regarding reading and math achievement of student groups by ethnicity. The researchers warn,

> Differences in teacher expectations are important not only because they can influence teachers' subjective judgments of their students' academic abilities and

> grades, but also because when teachers hold different expectations for particular groups of students, they may engage, support, and teach their students differently (p. 124).

Garcia and Chun (2016) also studied elementary teachers' explicit and implicit expectations for student achievement based on student race/ethnicity. The found that while teachers' explicit expectations had the largest impact on reading achievement, teachers' *implicit* prejudicial attitudes also had a significant influence on mathematics achievement. These results were partially attributed to the tendency for elementary teachers to more explicitly display higher expectations for reading than for math, suggesting that teachers need to purposefully and explicitly hold high expectations for student achievement, regardless of the content area.

Colorblind racism and context-neutral content. Educators who claim to be colorblind to racial differences between their students generally believe they are making a positive statement that they treat all of their students equally (Ullucci & Battey, 2011). Instead, colorblindness "at its heart contends that racial and ethnic identity are irrelevant" (p. 1206). *Colorblind racism* is a phrase used to describe the denial of racial patterns of inequality, despite evidence that gaps in academic achievement exist (Martin, 2009). Diggles (2014) agrees,

> Color-blindness also perpetuates racist ideologies by denying the system of privilege and oppression that exists on the basis of race. When this system is ignored or minimized, the disparities that exist between racial minorities and Whites are erroneously attributed to the shortcomings of those minorities (p. 33).

Educators with colorblind mindsets lack the racial understanding needed to reach pedagogical success with racially diverse populations (Milner, 2012b). Teacher who claim to be colorblind, even when confronted with data confirming an achievement gap, tend to blame low levels of achievement on students' family or background instead of considering the contribution of structural inequities within the school system (Battey & Franke 2015).

Mathematics is often considered to be one of the few colorblind and value-free fields of study (Bonner, 2014; Kelly, 2009). Math teachers often believe numbers comprise a universal language of mathematical understanding that transcends cultural and racial differences. This perspective of math education as free from bias helps to keep inequitable systems in place (Ukpokodu, 2011). Colorblind attitudes allow racial stereotypes to remain covert, hindering potential conversations that could lead to change in dispositions regarding math instruction (Battey & Franke, 2015). Ullucci and Battey (2011) argue that color consciousness, rather than color blindness, should be the collective goal of education. Educators need to overcome this mindset if they want to increase the educational opportunities provided to vulnerable students (Milner, 2012b).

As mentioned previously, student outcomes and data disaggregation remain statically focused on results from standardized testing (Gutiérrez, 2008; Milner, 2012a; Milner, 2013; Reardon, 2013). This narrow perspective tends to ignore all other aspects of mathematical literacy, such as real-world mathematical connections or postsecondary readiness (Gutiérrez, 2008, p. 360). Results of such testing "do not adequately explain why some students are not performing well or the other aspects of students' knowledge that do not show up on examinations" (Milner, 2013, p. 5), as assessment data alone does

not reflect the educational opportunities and experiences of individual students (Gutiérrez, 2008; Milner 2012b). This further emphasizes the need for research on educational inputs within the control of schools and teachers instead of static student achievement outputs.

Gatekeeper mathematics. Access to rigorous college preparatory math curriculum and higher-level math courses remains a systemic inequity in the field of math education (Flores, 2007). Mathematics, specifically Algebra classes, are often called "gatekeeper" courses, as successful completion puts students on an accelerated path towards more advanced course options, helping to ensure greater opportunities upon graduation (Buckley, 2010). According to Gojak (2013), "Research shows that students who complete a mathematics course beyond the level of Algebra 2 are more than twice as likely to pursue and complete a postsecondary degree" (n.a.). Gatekeeper courses have become tools for predetermining which students are and are not capable of succeeding in advanced math courses and provide the key to the gate accordingly (Stinson, 2004). Students who do not successfully complete college algebra, one of the most notorious gatekeeper courses, are often unable to pursue certain majors, if they graduate at all (Rech & Harrington, 2000). Affected students are then much more limited in their career choices, particularly in STEM-related fields (Buckley, 2010; Gojak, 2013; Kelly, 2009; Rech & Herrington, 2000).

Battey (2013) studied the relationship between math coursework, income, socioeconomic status, and race. National data were analyzed to determine the racial earning differentials attributable to previous mathematics coursework existed at three points between 1982 and 2004. This research revealed that though students across all

racial groups were taking more advanced mathematics courses, Whites students remain in a position of advantage that totaled in the hundreds of billions of dollars. Other studies have also confirmed the negative impact of gatekeeper courses on minority students, females, and those from low socioeconomic households (Stinson, 2004). Buckley (2010) agrees,

> Despite the critical role mathematics plays in young people's educational lives, students of colour and students from lower SES backgrounds have been routinely denied adequate instruction and learning experiences in the subject. As a result, mathematics has served as a gatekeeper to opportunities, such as mathematics- and science-based majors and careers (p. 51).

Though the "gatekeeper" label is usually applied to high school and college courses, inequitable math educational opportunities are shown to be a problem as early as prekindergarten. Access to a high-quality math education from Kindergarten through 12th grade can empower students by preparing them for future challenges in college, careers, and their everyday worlds (Buckley, 2010). Lee (2012) traced academic growth trajectories in mathematics throughout students' P – 12 schooling to determine if gaps in college readiness between racial and social groups were present at various benchmarks throughout their education. Examination of longitudinal data from three separate national longitudinal data sets revealed significant racial/ethnic gaps in college readiness at multiple points between Prekindergarten and high school graduation. While White students were generally on-track for college readiness at all grade levels, Hispanic students fell behind in college readiness in 3rd grade on average and African American students fell progressively more behind throughout their entire P – 12 Education.

Inequitable educational opportunities have been documented at all grade levels but are most prevalent in the form of ability grouping in elementary grades, and through course tracking in high school courses (Kelly, 2009). Buckley (2010) identified similar inequities in regards to secondary course tracking, stating, "Achievement in mathematics is linked to course-taking patterns, with low achievement being traced to low access to advanced mathematics courses" (p. 54). Tracking practices can begin years before a student enters high school when some students are permitted to take Algebra I, usually a high school math course, in middle school. Strict systems of course prerequisites beginning with Algebra I do not allow students to attempt higher-level math courses without following a prescribed sequence, making it nearly impossible for students who start off on lower tracks to ever access math courses that best prepare them for a postsecondary education (Riegle-Crumb & Grodsky, 2010). Callahan and Shifrer (2016) studied the course taking patterns of English Language Learners and discovered that placement in ESL (English as a Second Language) courses precluded equitable access to higher-level college preparatory courses. Perceived language deficits automatically place these students on a lower academic track than their English-speaking peers, thereby equating English proficiency with higher intelligence (2016).

In terms of access, research by Riegle-Crumb & Grodsky (2010) identified positive changes in the level of African American and Hispanic student representation in advanced math courses, such as Precalculus and Calculus. However, despite increases in enrollment in advanced courses and participation on Advanced Placement Exams by traditionally underserved students, the research uncovered stark differences in achievement between African-American and White students in both Precalculus and

Calculus even larger than the achievement gap in non-advanced courses (2010), confirming that there is still work to be done to ensure equitable instructional experiences in AP math classes. Findings are further supported by Minor's (2016) longitudinal study of racial differences in math test scores and advanced course-taking patterns. Significant differences were identified between test scores of African-American and White students in advanced mathematics courses, despite an increase in the number of African-American students enrolled in advanced courses --"Thus, even though African American advanced mathematics students are keeping pace with their White peers, the African American-White achievement gap is not closing" (p. 206).

Teacher quality and experience. According to Flores (2007), "The least prepared teacher recruits are disproportionately found in under-resourced, hard-to-staff schools serving predominantly low-income and minority students in central cities and poor rural areas" (p. 32). Teacher quality is an important school-level factor found to influence student achievement (Chetty, Friedman, & Rockoff, 2014). Kalogrides and Loeb (2013) arrived at similar conclusions while studying the distribution of novice teachers in three large urban districts. After examining data describing patterns of student sorting, they found that classrooms with the lowest achieving and highest minority and low-income students were the most likely to have novice teachers, exposing them to less experienced, lower quality instructors than their more advantaged peers.

Goldhaber, Lavery, and Theobald (2015) wrote about the "teacher quality gap" within their study of the dispersion of high-quality teachers across various indicators of student disadvantage, including free and reduced lunch programs status, race/ethnicity, and prior academic performance. Data collected from all school districts across

Washington State confirmed that teacher experience, licensure exam scores, and value-added estimates of effectiveness were inequitably distributed across every student disadvantage indicator at all grade levels. Minor, Desimone, Spencer, and Phillips (2015) also found this to be true at the national level in a study by of data analyzed from the Early Childhood Longitudinal Study- Kindergarten Cohort (ELCS-K), indicating that teachers of vulnerable students have fewer years of experience, are more likely to have alternative certifications, and are less likely to have advanced degrees.

Access to high-quality resources. The opportunity gap also includes inequitable access to adequate curricular resources and materials. Flores (2007) utilized national data sets to study the academic experiences of African American, Latino, and White student groups. Data revealed that on average, African American and Latino students received less funding per student than their white counterparts and were less likely to have regular computer access at school. More recently, Brown, Wohn, & Ellison (2016) studied the online information-seeking behaviors of high school students from low-income communities as they searched for information about colleges. Many students who came from households without internet access expressed their frustration with restrictive school internet policies, such as highly restrictive search filters and strict time limits in computer labs. As the authors point out, "Programs, curriculum, and resources designed to promote college access, especially resources designed to be delivered online, should reflect the varied contexts in which students learn and through which they gain the support they need to make post-secondary transitions" (p. 113). Reardon (2013) arrived at comparable conclusion after studying the achievement gap based on household income over a 50-year

timespan, noting that school districts need to proactively ensure equitable access to educational resources, such as computers and libraries.

Arguments in favor of gap analysis. Arguing for the importance of achievement gap analysis, Lubienski (2008) contends that continued analyses of gaps in student achievement supports the notion that student achievement is malleable and is used to inform future educational policies and research. Through achievement gap analysis, researchers "can illuminate just when those gaps begin, under what conditions they grow or shrink, and what consequences underserved students ultimately suffer because of the gaps" (p. 353). Reardon's (2013) longitudinal research investigating achievement gaps among social classes in the United States supports this perspective using a comprehensive analysis of the relationship between student academic achievement and family income in the U.S. spanning 50 years. After determining that the income achievement gap has grown significantly over the past three decades, Reardon (2013) was able to offer suggestions based on these findings for ways new economic policies and school practices can respond to growing disparities in academic achievement, such as increasing access to high-quality teachers and curriculum.

Achievement gap analysis can also help researchers and practitioners identify student groups in the need of support or intervention. Riegle-Crumb and Grodsky (2010) studied the academic outcomes of racial/ethnic subgroups in two advanced math courses, Calculus and Pre-Calculus, by reviewing course-taking patterns, high school transcripts, and survey data obtained from a national cohort of high school seniors participating in the Education Longitudinal Study of 2002. Results indicated that despite an increase in African American and Hispanic student representation in these advanced math courses,

the achievement gap was even more pronounced than in lower-level math courses. Riegle-Crumb and Grodsky (2010) warn, "Without levels of achievement comparable to those of their white peers, minority students taking the most advanced high school math courses remain in a position of disadvantage" (p. 250), revealing the need for more research and support for the marginalized students in advanced math classes, despite increases in access to higher-level coursework.

Culturally Responsive Education

Culturally Responsive Education (CRE) is an overarching term used to describe the critical ideologies, dispositions, and practices associated with providing an equitable and accessible education for diverse student populations (Dover, 2013). According to Pitre (2014) "Rigorous academic instruction is the foundation of the curriculum in high-performing, high-minority schools" (p. 215). Unfortunately, not all students are afforded the opportunity to enroll and succeed in high-level secondary and postsecondary courses and are instead subjected to low-level math tracks focused rote procedures and computation with little context or connections (Buckley, 2010; Callahan & Shifrer, 2016; Stinson, 2004). Culturally responsive teachers acknowledge the economic and democratic inequities facing marginalized student groups and work to make content accessible by building upon the background knowledge students bring with them into the classroom.

A brief history of culturally responsive education. The field of multicultural education was developed to confront the boundaries of inequity and to increase curricular access for marginalized students increased access to curriculum across all content areas (Hinnant-Crawford, 2016). CRE "integrates critical pedagogy's emphasis on sociopolitical consciousness with multicultural education's commitment to culturally

diverse content" (Hand, 2012, p. 5). Culturally responsive educators work to create equitable opportunities for learning that increase student achievement in hopes of closing the opportunity gap facing vulnerable students (Hand, 2012). Howard (2001) studied characteristics of effective culturally relevant educators as understood from the perspectives of students. The most effective teachers were described as consistently communicating a caring attitude, capable of building a community within the classroom, and continuously engaging all students throughout the learning process (Howard, 2001). A caring, supportive classroom environment with high expectations for all students is consistently found in studies describing the classroom environment of successful teachers (Esposito, 2009; Gregory & Weinstein, 2008; Howard, 2001; Ladson-Billings, 1995a; McKown & Weinstein, 2008).

Aronson and Laughter (2016) describe CRE through two separate strands of teacher education: *pedagogy*, a teacher's approach to teaching based on his or her attitudes and dispositions, and *teaching*, the methodology and practice a teacher enacts in the classroom. In order to fully understand CRE, it is necessary to address
The historical foundation of CRE is rooted within two seminal frameworks – Culturally Relevant Pedagogy (Ladson-Billings, 1995a) and Culturally Responsive Teaching (Gay, 2002).

Ladson-Billings (1995b) coined the term *Culturally Relevant Pedagogy* as a pedagogy committed to collective empowerment dependent upon teachers understanding their students' cultural backgrounds as assets rather than deficits (1995b). While studying successful culturally relevant educators, Ladson-Billings (1995a) did not observe specific patterns within their practice. Instead, she identified commonalities within their

educational philosophies – each had an ethic of caring, a feeling of personal accountability to their students, and were aware and responsive to their students' cultures. Thus, CRP does not include a list of effective teaching strategies, but a set of assumptions and beliefs about students and the purpose of education. These assumptions include (a) all students must experience academic success within the classroom, (b) students must maintain an appreciation for their own culture, as well as the cultures of others, and (c) students' learning must extend beyond the confines of the classroom and be used to solve real-world problems.

More recently, Ladson-Billings (2014) has reflected on the use, and at times misuse, of her original CRP definition. She expressed frustration with superficial interpretations and integration of culture in the name of CRP, such as monthly multicultural celebrations in the classroom, instead of fully integrating cultural perspectives into the curriculum or pushing students to think critically about the status quo (2014). Instead, she praises a "remix" of her original definition, praising Paris' (2012) culturally *sustaining* pedagogy, which "supports the value of our multiethnic and multilingual present and future" (p. 93). Culturally sustaining pedagogy encourages practitioners to hold a more fluid and complex perspective on culture with an explicit goal of perpetuating and fostering multicultural practices and perspectives for students and teachers (2012).

Gay (2002) defines culturally responsive teaching as "using cultural characteristics, experiences, and perspectives of ethnically diverse students as conduits for teaching them more effectively" (p. 106). Essential elements of culturally responsive practices include building a thorough understanding of cultural diversity, implementing

culturally relevant curricula, demonstrating cultural caring through a supportive classroom community, and effectively communicating cross-culturally with diverse student populations. Acknowledging teachers' difficulty in connecting theory to practice, Gay (2013) explicitly linked the theory of culturally responsive teaching to practical classroom application by describing four actions they can take to begin implementing CRT. First, teachers must restructure their own deficit attitudes and beliefs about marginalized students into more positive instructional expectations – "Teachers genuinely committed to transforming learning opportunities for students from these communities must identify, honor, and engage these resources or funds of knowledge in their reform efforts" (p. 34). Next, culturally responsive educators need to acknowledge that they will most likely be met with opposition and have to combat resistance throughout implementation. Third, teachers need to understand how and why culture and difference are foundational to culturally responsive teaching, as culture is an everyday part of a student's life. "Since culture and difference are essential to humanity, they should play a central role in teaching and learning" (p. 61). Finally, culturally responsive instructional practices should be shaped by the local context and designed to meet the specific needs of the target population instead of attempting to use a single set of strategies that are deemed effective for any and all students.

Consistent with the philosophical beliefs of Ladson-Billings, contextual differences between individual classrooms makes it impossible for culturally responsive teachers to adopt a specific set of instructional strategies (Gay, 2013). The following section address CRE research as it specifically pertains to mathematics education.

Culturally responsive mathematics education. Math teachers often find it particularly difficult to apply culturally responsive teaching within the context of their content (Bonner, 2009). Goldenberg (2014) agrees, "Besides science, mathematics, as well, has often been the most difficult topic for teachers to embrace students' cultural capital because on the surface, it would appear that there are not ways for students' culture to relate to the curriculum or teachers' lesson plans" (p. 20). Culturally Responsive *Mathematics* Teaching provides a supportive framework for teacher implementation by merging the ideologies of CRE with teachers' mathematical content knowledge (Aguirre & del Rosario Zavala, 2013; Bonner, 2009). Dornoo (2015) explains,

> In the mathematics classroom, teachers can help students understand that even though there are certain elements of mathematics that are universal— such as counting, locating, measuring, designing, playing, and explaining—there are differences in the ways diverse cultural groups view some of the major aspects of mathematics (p. 84).

This approach allows teachers to capitalize on the background knowledge students bring with them into the classroom in an effort to help them make meaningful, real-world connections outside of the classroom (Harding-DeKam, 2014; Hinnant-Crawford, 2016). Consistent with philosophies of CRE, there is no specific formula or set of instructional strategies for teaching culturally responsive mathematics, as every classroom and community setting is situated within a different culture. Bonner and Adams' (2012) framework for Culturally Responsive Mathematics Teaching consists of four cornerstones consistently observed while studying successful culturally responsive math

educators. The first cornerstone, *knowledge*, includes not only knowledge of mathematical content, but also knowledge of students' home lives and cultures, familial backgrounds and values, and interests. *Communication*, the second cornerstone, includes a wide range of effective communication skills teachers use to connect math content and student culture. Teachers also use their communication skills to convey high expectations for learning while also creating a caring classroom environment. The third cornerstone, *relationships and trust*, requires nurturing relationships not only with students, but also their families and surrounding community. The fourth cornerstone, *reflection and revision*, encourages teachers to reflect and revise their practice, responding to student feedback and insights.

Bonner (2014) later added a fifth cornerstone, *pedagogy and discipline,* which was dependent upon teachers' clear communication of high expectations for both learning and behavior – "There was no classroom management system or plan that was separate from pedagogical practice; rather, student engagement and interest were almost inherent in practice," (p. 392). Culturally responsive mathematics educators maintain a firm and controlled focus on academics in the classroom, making discipline problems almost nonexistent. This allowed teachers to keep students engaged and focused on the mathematics without wasting valuable instructional time on classroom management problems.

Aguirre and del Rosario Zavala (2013) also created a CRE framework for math education after studying the successful implementation of CRE ideologies in math classrooms. Their framework consists of two dimensions: community funds of knowledge and teaching mathematics for social justice. *Community Funds of Knowledge*

are the familiar activities that students participate in at home with their families and within the community that culturally responsive educators connect to mathematical content within the classroom (p. 166). *Teaching mathematics for social justice* affords students opportunities to challenge inequitable structures through mathematical inquiry and investigation. This framework guided the creation of a lesson analysis tool comprised of eight dimensions – intellectual support, depth of student knowledge and understanding, mathematical analysis, mathematical discourse and communication, student engagement, academic language support, use of language scaffolding strategies, funds of cultural and community knowledge, and use of critical knowledge for social justice.

Jett (2013) added additional insight into teaching mathematics through a culturally responsive lens by investigating his own practices in a collegiate mathematics classroom setting. In an effort to access the prior knowledge of his African American college students, he gathered information about their cultures, backgrounds, interests, and strengths to design mathematical tasks related to their identities. He was deliberate in his choices to use empowering discourse to build students' confidence in their math abilities as well as to use math as an analytical tool to examine issues within social justice. Finally, he facilitated critical dialogue and collaborative problem solving, connecting his class' math objectives with students' diverse mathematical perspectives. Jett (2013) found that his efforts to infuse CRE into the mathematics classroom challenged his diverse student population to think critically about the content in meaningful ways.

CRE/CRME and student outcomes. While achievement discourse often maintains static focus on data collected from state assessments, numerous studies have

pointed to additional benefits of CRE beyond students' scores on standardized tests (Milner, 2011). For example, culturally relevant pedagogy is reported to increase students' feelings of empowerment, as teachers encourage them to question inequitable structures while contributing to their own learning with agency (2011). Hubert (2014) studied African American students' perceptions of their teachers' use of culturally relevant pedagogy within the mathematics classroom, focusing on teacher behaviors and students' levels of interest in and attitudes towards mathematics. Student interviews conducted after course completion indicated that, in addition to an average increase in math performance by one full letter grade, all students had a greater interest in mathematics because of the culturally responsive nature of the course. Students identified a home-like classroom environment, teacher ethic of caring, regular opportunities for student participation, and technology use as four areas with the greatest impact on their learning. As a result, students were left with increased confidence and motivation.

CRE allows students the opportunity to see themselves, their communities, and their culture's important contributions within the curriculum (Milner, 2011). Chun and Dickson (2011) studied the relationships between culturally responsive teaching, parental involvement, and academic performance of Hispanic middle school students in a community along the US-Mexico border region. They found that culturally responsive teaching and parental involvement both impacted students' academic performance indirectly by increasing their academic self-efficacy and sense of belonging at school. Bui and Fagan (2013) also demonstrated CRE's impact on academic achievement while integrating a culturally responsive teaching framework into two fifth-grade reading classes in an urban elementary school composed primarily of English Language Learners

from low-income households. Data analysis revealed statistically significant gains in word recognition, reading comprehension, and story retell, supporting the integration of culturally responsive teaching into reading instruction.

Garza (2009) investigated the perceptions of a group of Latino and White high school students in regards to how their teachers conveyed caring behaviors and attitudes. Five teacher behaviors were identified as most important to both Latino and White students using a constant comparative analysis: behavior that facilitates a culture of success and positive self-esteem, kind teacher dispositions, unrestricted teacher availability, showing a personal interest in students' lives, and affective academic support within the classroom. Though the five behaviors were similar across both student groups, the priority and importance of each of behavior for each group was unique – Latino students most frequently mentioned academic support as the most important priority, while White students placed greater value on relationships. Garza (2009) advises that teachers explicitly convey purposeful and culturally responsive caring unique to students' individual needs because "caring for students may look different from what common practice dictates" (p. 297).

Difficulties and cautions for CRE/CRME implementation. According to Ladson-Billings (2014), "Teachers undertaking culturally informed pedagogies take on the dual responsibility of external performance assessments as well as community- and student-driven learning" (p. 83). Implementing culturally relevant instructional practices becomes increasingly more difficult as the pressure to increase scores forces non-tested content to be swept under the rug (Sleeter, 2012). Teachers often find that rich, culturally relevant curriculum is at odds with the multiple-choice thinking imposed by high-stakes

testing and accountability requirements. Educators need to be aware that they may encounter a significant amount of opposition when implementing CRE (Gay, 2013). In order to confront potential forms of resistance, culturally responsive educators must first "acknowledge and understand its causes, manifestations, and consequences" (p. 56).

Sleeter (2012) named multiple factors that could contribute to an educator's resistance to culturally responsive teaching. First, overly simplistic conceptions of cultural responsiveness often misrepresent its purpose and complexity. Irvine (2010) found that the simplistic, surface-level understanding of culturally relevant pedagogy held by many educators makes it almost impossible to bridge the cultural gap. Though well-meaning, these teachers enact cultural responsiveness simply by acknowledging multicultural holidays or including ethnically/racially diverse posters within the classroom. Oversimplifications and misconceptions of CRE have been identified repeatedly as inhibitors to its implementation (Gay, 2013; Irvine, 2010; Sleeter, 2012). This problem becomes even more complex when considering CRE for mathematics, as many math teachers have an overly objective view of the subject matter, hindering them from using CRMT to engage students in critical dialogue (Timmons-Brown & Warner, 2016). Sleeter (2012) warns, "Oversimplified and distorted conceptions of culturally responsive pedagogy, which do not necessarily improve student learning, lend themselves to dismissal of the entire concept" (p. 572).

Young (2010) conducted a critical case study of one urban school's attempt to implement culturally responsive pedagogy as a school-wide pedagogical tool. Administrators and teachers collaborated with the researcher to define and actualize culturally relevant pedagogy on the campus. Survey data from faculty members revealed

an overall sense of confusion surrounding multiple facets of culturally relevant pedagogy. For example, when asked to describe their understanding, not a single participant mentioned "academic success," one of Ladson-Billings (1995b) three essential components of culturally responsive pedagogy. Saint-Hilaire (2014) also voiced concerns regarding ambiguities and vague understandings of cultural responsiveness, pointing to the variety of different terms used in the research when referring to the same pedagogy: culturally congruent, culturally responsive, culturally relevant, and culturally appropriate, to name a few.

In addition to ambiguous and unclear understandings of CRE, Young (2010) also noted difficulties in implementation because of teachers' implicit cultural biases, as well as the systemic racism that exists within standardized school settings. Teachers' preferences for the district's scripted, standardized curriculum inhibited them from effectively integrating CRE into their lesson plans. Ukpokodu (2011) arrived at a similar conclusion while investigating reasons math teachers did not engage in culturally responsive math teaching. Participants noted the convenience of prepackaged curricular materials and the district's strict focus on standardized testing as reasons for not engaging in culturally responsive practices. Ukpokodu (2011) concluded, "The crisis in mathematics learning among urban and low-income students is caused by school policies, curricula, and teaching practices that do not engage those students" (p. 48). Sleeter (2012) agreed with this notion, stating, "Education reforms that have dominated U.S. schools since the 1990s have been deliberately context-blind" (p. 565).

Schmeichel (2012) argued that the existence of CRE itself is problematic for the promotion of equity in education, as it implies that students from minority groups are

inherently different from white students, supporting the notion that natural differences can mean natural deficits. Educators may then feel encouraged to approach educating these students differently from their white students (2012). "While culturally responsive scholars strived to situate that difference positively, their work simultaneously situated white, middle class beliefs, behaviours, and cultural strategies as the norm, the centre of the continuum" (p. 222).

These perceived difficulties and cautions for CRE implementation, specifically in mathematics classrooms, further supports the need for more extensive research and training to develop a deeper pedagogical understanding of CRME. Young (2010) agrees, "The void in scholarly research is not in the knowledge of theories but in the knowledge of how to implement them, particularly in a way that has a wide-reaching and sustainable impact on teacher education" (p. 259). The next section of this literature review addresses teacher preparation and development for CRE.

Building Teacher Capacity for Equitable Mathematics Teaching

Prospective teacher preparation. Sociocultural differences between teachers and students can create a significant gap in their lived experiences, leaving teachers blind to their students' unique circumstances. (Castro, 2010; Wager & Foote, 2013). Goldenberg (2014) states, "Understanding how students of color are typically not members of the 'dominant culture' is crucial to learning how and why non-White children are less likely to engage in school" (p. 2). Few preparation programs for pre-service teachers have been found to provide sufficient training in multicultural education, engaging students with only surface-level activities that provide little more than a superficial explanation of CRE (Assaf, Garza, & Battle, 2010; Castro, 2010; Ellerbrock,

Cruz, Vasquez, & Howes, 2016). Still, other programs have been found to not address any aspects of culturally responsive teaching whatsoever (Hayes & Juarez, 2012; Williams et al., 2016).

Vomvoridi-Ivanovic and McLeman (2015) investigated the self-reported challenges of mathematics teacher educators while teaching equity-focused math methods courses. These challenges fell into one of three categories: pre-service teachers' willingness to attend to equity issues, the teacher educators' own internal struggles concerning the meaning of equity instruction, and equity instruction's conflicting priorities with the realities of school accountability and curriculum requirements. Similarly, Assaf, Garza, and Battle (2010) studied the perceptions, beliefs, and practices of teacher educators in regards to their instruction in multicultural education and how their dispositions affected overall coherence of the program. Participant interviews, course syllabi, schedules, and assessments were analyzed to understand the intended role of CRE instruction within the program. The researchers concluded that the varying, and at times conflicting, beliefs and practices of teacher educators about multicultural education resulted in an incoherent teacher preparation program, lacking a shared purpose with focus on multicultural education. The teacher educators voiced feelings of anxiety when asked to discuss racial or socioeconomic issues in their courses and often gave inconsistent definitions of multicultural education. Not one participant was able to provide an example of how to integrate CRE into actual classroom practices, but all agreed that field-based experiences outweighed their own ability to teach for diversity. Assaf, Garza, and Battle (2010) recommended that teacher preparation programs

establish a centralized focus and definition of multicultural education if they hope to sufficiently prepare pre-service teachers to work with diverse student populations.

Though a substantial amount of research reveals a lack of in-depth instruction in social and cultural issues provided by teacher preparation programs (Hayes & Juarez, 2012), there are some studies of effective programs that make CRE a central focus of their instruction. Williams et al. (2016) studied the impact of one teacher preparation program with a purposeful focus on developing the cultural dispositions of pre-service mathematics teachers. Participants were interviewed at three points throughout the study to measure and compare their cultural dispositions. Upon entering the program, participant responses indicated a general awareness and recognition of inequities, but also conflicting dispositions towards deficit thinking that wavered between blaming students' backgrounds for low levels of achievement and stating negative opinions towards deficit thinking. During the program, participants indicated that they now recognized the importance of teaching in a culturally and linguistically responsive manner and acknowledged that they still had a lot to learn about CRE. By the end of the program, they exhibited positive changes in understanding how culture impacts teaching and learning mathematics, as well as how students' home culture impacts the school environment. Four of five participants in this study remained in culturally diverse schools for at least five years, leading the researchers to believe that if more teacher preparation programs worked towards developing positive cultural dispositions in pre-service teachers, more of these teachers would remain in culturally or linguistically diverse school settings. This notion is further supported by Thompson's (2013) study of the multicultural dispositions of a group of education majors. Results from participant pre-

and posttest Likert Scale responses revealed that instruction focused on developing positive multicultural disposition in teacher candidates can positively alter their perceptions throughout the program, helping them reach high levels of multicultural awareness.

Stressing the importance of teachers' dispositions and beliefs about diverse student populations, Gay (2010) stated, "It is inconceivable to me that teachers who have negative beliefs about ethnically diverse students and their cultural heritages as valid and viable educational resources can relate to them positively in personal and instructional interactions" (p. 150). An educator's effectiveness with diverse student populations is profoundly affected by his or her values and beliefs (Edwards, 2011). Therefore, teachers must possess a level of cultural awareness in order to experience success with diverse students. Edwards (2011) examined the relationship between the culturally responsive dispositions and the field experiences in an urban school setting of five pre-service teachers. Each teacher candidate's understanding of CRE was developed through three themes of relationship building in the classroom. The first theme, *interaction*, or getting to know their students both as learners within the classroom and outside of the classroom, was identified as the starting point for building relationships with students. The second theme, *ownership,* refers to the ability for a teacher to empower students through inquiry and a sense of community rather than simply providing them with the information through lecture. Finally, *accommodation* refers to providing students with their individual needs in order to be successful in the classroom. Together, these three themes were found to be essential to the positive development of participants' dispositions towards CRE.

Bringing equity to the forefront of teacher preparation would require a dramatic shift in goals and priorities (Cochran-Smith, et al., 2016). Specifically, programs would have to reconceptualize educational inequality and teachers' roles in challenging it, define the nature of teachers' practice for equity, and design and implement equity-centered curricula for pre-service teachers in order to achieve this task (2016). However, pre-service teachers are not the only educators in need of instruction in CRE. Experienced teachers also often report feeling unprepared to work with students from backgrounds different from their own (Sleeter, 2012; Turner et al., 2012). Adequate access to quality professional development is one route towards educating practicing teachers in the mindset and implementation of CRE.

Professional learning opportunities for practicing teachers. As more research emerges in support of CRE, the need to effectively educate teachers in implementing and sustaining equitable classroom practices becomes more apparent. Battey and Franke (2015) state, "Shifting the lens of professional development from one focused only on content to a perspective that sees teaching as participating in societal discourses changes how we understand teacher interactions in classrooms" (p. 9). PD for equitable instruction can provide space for schools to challenge deficit beliefs concerning the mathematical abilities of underserved students and work towards shifting the dominant equity and mathematics discourse (Desimone & Garet, 2015). PD opportunities can provide the time and space for equitable practices to grow.

Desimone and Garet (2015) identified five critical features of professional development programs that most often result in changes to teacher practice. First, effective PD is *content-focused*, engaging participants in activities that include relevant

subject matter and ways students can best learn that content. Second, teachers must be given opportunities to be *active in the learning process*, as opposed to passively listening to lectures. Third, the PD should be *coherent* and aligned to the school or district's content, goals, and activities. Fourth, it should take place for a *sustained duration* of time and result in 20 or more hours of contact time. Finally, it should encourage *collective participation* through which groups of teachers from the same grade, subject, or school participate together and grow as an interactive learning community.

Literature relevant to the present study addresses several important elements of PD models for equity that align with Desimone and Garet's (2015) characteristics of effective PD, including participants' shared talk and discussion, opportunities for reflection, and opportunities for professional networking. Teachers' shared talk can support teachers as they work through and discuss changes to their thinking and practice with colleagues (Bianchini, Dwyer, Brenner & Wearly, 2015). Reflecting on one's own teaching and learning is essential for teachers to address their own individual practice, as well as the cultural and institutional contexts within the school system (Rousseau & Tate, 2003). Building a professional network with other like-minded educators provides opportunities to collaborate, share ideas, support new teachers, and sustain current practices (Ritchie, 2012).

Sleeter (2009) conducted a case study of a second-year teacher enrolled in a master's program, analyzing various factors thought to promote professional growth. Throughout the study, the teacher was enrolled in Multicultural Curriculum Design, a graduate-level course created to deepen teachers' understanding of curriculum planning within the context of multicultural education. After implementing various strategies

throughout the course meant to engage students in multicultural education topics, the researcher identified several activities that were particularly valuable in promoting her professional growth – the student's self-reflection through writing activities, discussions with peers, and opportunities to learn from colleagues. The time provided for self-reflection helped the teacher make important connections between new learning and her current teaching philosophies and practices. Through structured dialogue with other professionals concerning different approaches to multicultural education, she gained new insights into possibilities she may otherwise not be exposed to in other contexts. This case study reinforced "the importance of creating contexts in which teachers can examine their own backgrounds and beliefs, interact with one another, and interact with ideas that stretch them intellectually" (p. 12).

Durden and Truscott (2013) expand upon the concept of self- reflection through the use of *critically reflectivity*, the self-examination of ways in which "experiences, beliefs, and expectations of culturally and linguistically diverse students impact teaching and learning" (p. 74). Their research sought to understand the reflective growth of three pre-service teachers as they learned about Culturally Relevant Pedagogy. Analysis of interview transcripts and reflective documents supported the use of purposeful critical reflection to develop teacher understanding of culturally relevant pedagogy. Through critical reflectivity, all three participants were able to make culturally relevant connections beyond the boundaries of their classrooms and into society and policy.

Crockett and Buckley (2009) coined the term *coflection* to describe the collaborative reflections amongst a group of teachers as they participated in a professional development opportunity. The authors define coflection as "an epistemic or

knowledge-generating process, captures the socially critical nature of the interactions among teachers within professional learning experiences that we believe are necessary for generating the kinds of knowledge teachers need to facilitate students' academic success" (p. 170). While comparing their two separate studies of teacher dispositions towards equity in mathematics PD, one at the elementary level and one at the secondary level, they discovered that teachers from both studies initially attributed students' problems with learning new material and low levels of achievement to inherent student ability. However, through facilitated coflection concerning equity in mathematics education, the focus of the dialogue shift towards ways they could improve their own classroom instruction to meet the diverse needs of their students instead of blaming students' inherent ability.

Timmons-Brown and Warner (2016) sought to identify the long-term effects of a two-day conference-style workshop for culturally relevant pedagogy in math classrooms as perceived by its participants. The researchers analyzed attendee's responses to pre- and post-surveys, as well as follow-up interviews conducted one year after the conference, and identified several long-term benefits of conference attendance. Data revealed that participants not only took the opportunity to network with other educators throughout the conference, but they also sustained a professional network supportive of culturally relevant pedagogy. Through this network, participants were able to continue sharing classroom experiences through ongoing professional dialogue, offering pedagogical support, and discussing effective practices. Conference attendance also helped participants to prioritize the development of positive teacher-student and student-student relationships within the classroom in order to reach students at a more personal level, as

well as better facilitate working relationships between students to promote cooperative learning.

Ritchie (2012) also emphasized the importance of forming and joining professional networks within his study of critical educators teaching for social justice. Qualitative interview data that documented the various life experiences, backgrounds, and motivations of eight critical P-12 teachers confirmed that professional networks were vital to the recruitment and retention of teachers using critical pedagogy. Richie (2012) concluded,

> Informal teacher networks exist within many P-12 schools in the United States, where teachers collaborate with one another to prevent isolation, offer emotional support, and share teaching ideas around social justice themes. Not only did teacher networks help the participants in deciding to become teachers, but also to sustain social and professional networks of critical educators (p. 126).

Professional networks provided a space for new teachers to ask questions and receive support as they continue learning about social justice, and experienced critical teachers are encouraged as they sustain their work.

Sustaining long-term change towards equitable instruction. One challenge faced by many PD programs and models is the inability to follow up with participants to ensure new knowledge and skills are successfully integrated into teacher practice (Killion, 2012). One option available to help sustain new learning is to utilize an instructional coach to facilitate ongoing teacher development. Desimone and Garet (2015) point out that many schools are moving away from one-time workshop models, acknowledging that PD is most effective when it involves ongoing activities throughout

the school year. According to Cornett and Knight (2009), "There may be approaches to professional development that are more effective than coaching, but a workshop without follow-up, the research clearly shows, is not one of them" (p. 209). At the time that this research was conducted, I was employed as a mathematics instructional coach and used my position and existing relationships with participants to engage in this research. This section outlines pertinent literature pertaining to instructional coaching as PD for equitable mathematics instruction.

Instructional coaching is considered to be "a professional development practice that bridges the gap between training and application of new learning in classrooms" (Killion, 2012, p. 274). Instructional coaches support teachers as they integrate new learning into their practice, promoting improvement through continuous feedback. After conducting a thorough review of research pertaining to instructional coaching, Cornett and Knight (2009) identified four major areas of teacher practice and pedagogy found to be impacted by coaching: teacher attitudes towards job satisfaction, implementation rates of new teaching practices, teacher efficacy, and teacher quality affecting student achievement. Their research led them to conclude that by improving the quality of instruction in the classroom, instructional coaching can have an indirect, positive impact student achievement (2009).

Desimone and Pak (2017) conceptualized an instructional coaching framework using the same PD framework previously reviewed by Desimone and Garet (2015) consisting of five key elements: content focus, active learning, sustained duration, coherence, and collective participation. This coaching framework allows instructional coaches to embed new learning into a specific content area, provide frequent

opportunities for practice and feedback, facilitate school wide improvement strategies and modifications, and align new learning with content standards, curriculum, and goals (2017).

It is important to note that approaches to coaching vary widely, as various coaching models exist throughout the country, making it difficult to measure its overall impact (Campbell & Malkus, 2011; Cornett & Knight, 2009; Teemant, 2014). Campbell and Malkus (2011) examined the relationship between elementary mathematics coaching and student achievement in a study of 36 elementary schools. Coaches provided on-site, collaborative PD focused on math content, pedagogy, and curriculum in an effort to increase the school's instructional capacity. After a three-year period, students enrolled in schools with elementary math coaches scored significantly higher on state standardized mathematics achievement tests than control schools with no elementary math coach (2011).

Teemant, Wink, and Tyra (2011) examined the effects of instructional coaching on teachers' use of sociocultural instructional practices designed for educating diverse student populations. Instructional coaches supported teachers as they engaged with research-based sociocultural principles of learning called The Five Standards Instructional Model. The Five Standards include *Joint Productive Activity* in which a teacher and small group of students create a shared product together, *Language and Literacy Development* through which sustained and supported opportunities are provided for students to read, write, and speak, *Contextualization*, to make connections between new learning and home, school, and community, *Challenging Activities* in which students are tasked with a performance challenge, support, and feedback to access challenging

content, and *Instructional Conversation* facilitated by teachers as they question and assist students through sustained, student-dominated academic conversations. Findings from this study highlighted a significant transfer of new skills from workshop setting to classroom setting, as well as teacher growth across individual sociocultural pedagogical standards. Teemant (2014) later investigated the longitudinal effects of these outcomes using pre- to post-intervention observations to measure transformation, as well as classroom observations one year after the initial intervention to measure sustainability. Results indicated that instructional coaching led to statistically significant pedagogical transformation and patterns of sustainable change in practice.

Integrating PD for equity and mathematics. Crockett and Buckley (2009) state, "The acquisition of knowledge for teaching should come through ongoing substantive professional development practices for mathematics teaching and learning" (p 172). Teacher training that integrates mathematical content knowledge and equity is necessary to combat deficit views about racially, ethnically, and socially diverse student populations (Battey & Franke, 2015). Gay (2013) agrees, "Connecting culturally responsive teaching to specific subjects, skill areas, and other regular functions performed in classrooms also is crucial to determining teachers' levels of ownership of and investment in it" (p. 64). Literature addressing PD for equity and mathematics teaching is currently limited, but growing (Bianchini, et al., 2015; Timmons-Brown & Warner, 2016; Wager & Foote; 2013).

Effective professional development activities provide opportunities for participants to collaborate and discuss new learning with colleagues in order to enact change in teacher practice (Bianchini, Dwyer, Brenner & Wearly, 2015; Crockett &

Buckley, 2009; Hudley & Mallinson, 2016). Hudley and Mallinson (2016) studied a culturally and linguistically supportive PD series based on the specific needs of its Science, Technology, Engineering, and Mathematics (STEM) educator participants. The researchers led participants in group discussions about their previous experiences and interactions with culturally diverse students in academic settings, then suggested strategies to make their STEM classrooms more linguistically and culturally supportive of all students. Participants found the PD very impactful, noting a serious lack of PD opportunities for STEM teachers to address linguistic and cultural issues to "develop the skill- not just the sentiment- necessary to most effectively serve students from underrepresented groups and close opportunity gaps in U.S. STEM education" (p. 5).

Bianchini et al. (2015) examined the strengths and limitations of four professional learning strategies in promoting math and science teachers' dialogue about equity over a series of PD seminars. The learning strategies included teacher research, personal experiences, reform-based instructional practices, and examination of demographic, course taking, and achievement data at the school, state, and national levels. After initial data analysis to determine each strategy's strengths and limitations, they were placed on a continuum ranging from most strengths in facilitating teacher talk to most limitations. After seminar recordings, teacher interviews, and written reflections were analyzed to determine opportunity, length, and substance of equity talk, researchers determined that examination of school/state/national data was found to have the most strengths in promoting teacher talk about equity, followed by teacher research, reform-based instructional practices, and finally, personal experiences. These conclusions prompted Bianchini et al. (2015) to advise professional developers to be thoughtful and purposeful

when considering the structure and strategies used in a professional development order to optimize opportunities for professional dialogue surrounding equity and mathematics.

Wager and Foote (2013) observed teachers as they participated in a monthly PD series over the course of a year to discuss and consider issues of equity and access within their own mathematics teaching as it connected with their own backgrounds and experiences. They analyzed ways in which educators' personal lived experiences, as well as levels of participation in whole-group discussions about equitable mathematics instruction, influenced their beliefs and identities as math educators. Analysis of teacher reflections and interviews revealed that teachers' backgrounds and experiences affected the levels and types of engagement throughout the PD, as well as where they located praxis for equity in mathematics. The authors advised, "Facilitators need to be aware that teachers may start with a lens of mathematics, or equity, or both and recognize how these varying lenses provide access to the figured world of equitable mathematics pedagogy" (p. 32).

Battey and Franke (2015) detailed an integrated math and equity professional development as they attempted to challenge teachers' deficit dispositions of their students' abilities. Using a combination of monthly workgroup meetings and on-site support to observe and provide feedback, the researchers worked with teachers to rethink deficit narratives about minority students by building on what students *did* understand and contribute: "By focusing on students' mathematical contributions and the classroom practices that constrain/enable student participation, both the mathematics and student opportunity to learn are central in the professional development" (p. 12). Their approach helped teachers to focus on what they themselves could do to help students develop

mathematical concepts instead of labeling students based on their perceived mathematical abilities.

Professional development experiences are found to be most effective when they explicitly connect and align to teachers' content areas (Desimone & Garet, 2015). Additionally, Gresalfi and Cobb (2011) found that "changes in the types of instructional practices with which teachers identify, and thus in their personal identities as mathematics teachers, involve changes in their motivations for teaching" (p. 271). Aguirre and del Rosario Zavala (2013) attempted to make CRME PD experiences more concrete by developing a lesson analysis tool to guide teachers as they assess and critique culturally responsive math lessons. The CRMT lesson analysis tool contains guiding questions to facilitate dialogue and reflection over eight dimensions of CRMT across the categories of mathematical thinking, language, culture, and social justice. Participants engaged in PD activities using the CRMT lesson analysis tool to critique a commercially available math lesson, rate and discuss their own math lessons, and develop their own CRMT goals for the year. The collaborative PD framework allowed teachers to critically reflect and discuss their practice and make substantive changes towards more equitable mathematics instruction. By the end of the PD workshop series, participants began to self-evaluate strengths and areas for improvement of their own lessons using the provided rubric dimensions and adapt their lessons accordingly.

According to Gay (2013), "Teachers tend to use instructional examples culled from their own personal experiences and those of people and communities similar to themselves. But ethnically and culturally diverse students and teachers often do not have these reference points in common" (p. 67). Taylor (2012) agreed with this sentiment and

sought to identify ways for teachers to purposefully integrate students' out-of-school contextual experiences into the classroom. The PD framework chosen, the Reflection Connection Cycle, maximized participants' reflection time over various assigned readings, their own experiences, the experiences of their colleagues, and connections between out-of-school and in-school learning. Monthly group meetings and home/classroom assignments were designed to support reflective connections between readings and participants' own practice. Analysis of teachers' written lessons built on students' informal mathematical understandings progressed from lessons built on general contexts, such as gardening and sports, to lessons indicating a greater concern and understanding for real-world contexts their students engaged with outside of school.

Future Research in Equitable Mathematics Teacher Development

In Battey and Franke's (2015) view, "As a field, we need to find ways to integrate equity into the core of mathematics professional development as a way of supporting different relationships for urban students and mathematics" (p. 7). Research concerning CRE and mathematics education often frames and analyzes culture independently of the mathematics content (Milner, 2017). However, math's gatekeeper status has kept inequities in place for far too long. Aguirre et al. (2017) agree –

> There is a long-standing, thoroughly documented, and seemingly intractable problem in mathematics education: inequity. Children of certain racial, ethnic, language, gender, ability, and socioeconomic backgrounds experience mathematics education in school differently, and many are disaffected by their mathematics education experience. (p. 125)

The authors suggest four political acts, acts that address power, privilege, and inequity, for MERs to help move the field of mathematics education forward:

1. Enhance mathematics education research with an equity lens
2. Acquire the knowledge necessary to do genuine equity work
3. Challenge the false dichotomy between mathematics and equity
4. Expand the view of what counts as "mathematics"

Research concerning the preparation of prospective teachers to work with diverse student populations, as well as PD for practicing teachers, is repeatedly mentioned as an area in need of more research (Bianchini et al., 2015; Childs, 2017; Hudley & Mallinson, 2016; Vomvoridi-Ivanovic & McLeman, 2015). Improving professional learning opportunities for culturally responsive teachers is an important step towards ensuring all students have access to an equitable mathematics education (Bianchini et al., 2015)

Aguirre et al. (2017) believe that it is time for mathematics education researchers (MERs) to take on equity as our collective professional responsibility – "We cannot wait another decade. MERs need to start now, collectively, and use our power toward a more humane, just, and equitable mathematics education" (p. 141). This study hopes to address the four political acts mentioned previously by engaging local teachers in a professional development series over culturally responsive mathematics education.

Chapter III

Methods

Guided by the Culturally Responsive Mathematics Education Framework, this study explored two research questions: 1) How do teachers' sociocultural and mathematical backgrounds and experiences influence their understanding and approach to equity and access in math education? and 2) How does professional development for CRME influence participants' understanding and approach to equitable and accessible math education? While working as a mathematics instructional coach, I engaged in action research to bridge the gap between culturally responsive theory and practice by facilitating a five-week PD series centered on cultural responsiveness in math education for a group of elementary math teacher volunteers, followed by six weeks of classroom observations and interviews, to address the research questions.

This chapter begins by reviewing the research perspective and design chosen to carry out this investigation and describing the research site and participants. All procedures followed throughout the research process will then be outlined from beginning to end, including a detailed description of all professional development activities. Afterwards, the data collection and analysis procedures will be explained to provide insight into how findings were identified, including descriptions of qualitative data sources, coding processes, and the identification of themes for individuals, as well as across all participants. This chapter concludes by revisiting the limitations of the study and establishing trustworthiness.

Research Perspective

Committed to the transformative social justice agenda, participatory action research allows for a collaborative framework through which practitioners critically reflect upon and transform their practice in hopes of bringing about meaningful social change within their community (Brydon-Miller & Maguire, 2009). This action research is aligned with the critical theory perspective, as it is "concerned with equity, self-reliance, and oppression problems." (Herr & Anderson, 2014, p. 36), with an emancipatory emphasis. Critical ontology subscribes to the notion that reality is created through power struggles, constructed by social, political, cultural, ethnic, and economic biases that have crystallized over time (Guba & Lincoln, 1994). Knowledge, therefore, is contextual and value-mediated, dependent upon the circumstances surrounding the researcher and participants (1994).

Creswell (2013) expands upon this definition of critical epistemology, stating, "Reality is known through the study of social structures, freedom, and oppression, power, and control. Reality can be changed through research" (p. 37). Critical researchers first acknowledge these power struggles, then call for action to change that reality (2013). The present study situates the values and experiences of math teachers in opposition to those of marginalized student groups in a sociopolitical context in an effort to reveal how traditional approaches to math education ultimately favor dominant student groups.

Brydon-Miller & Maguire (2009) note three types of change that have the potential to result from participatory action research: the development or expansion of participants' critical consciousness, improvement to the lives of people involved, and transformation of societal structures and relationships. This study hopes to encourage its participants,

including the researcher, to challenge the inequity and inaccessibility of mathematics education by expanding upon their critical consciousness and purposefully make changes to current practices that favor certain groups of students over others.

Research Design

This action research study was conducted using a qualitative case study design in an effort to provide a rich, descriptive account of participants' professional learning experiences, as well as to identify potential changes in their understanding and approach to equitable math teaching throughout the PD series. My role as a math instructional coach within the research site, a midsized rural school district, allowed me to facilitate ongoing PD opportunities focused on equity and access in math education for nine elementary math teachers within the scope of my regular job responsibilities. Substantial amounts of descriptive data were collected from multiple sources to fully represent the case and participants, including video and audio transcriptions from PD discussions and individual interviews, autobiographical reflections from participants, classroom observations, field notes, and open-ended questionnaire responses.

Setting and Participants

This research was set within a midsize rural school district serving between 5,000 and 6,000 students and employing between 300 and 400 teachers. District demographic data in terms of race/ethnicity, provided in Table 3, reveal significant differences between teacher and student race/ethnicity, particularly between the Hispanic and White student and teacher groups, consistent with trends identified at both the state and national levels (Gay, 2013). Additionally, consistent with findings regarding opportunities to learn and the teacher quality gap between student groups, (Goldhaber et al., 2015), 60% of

elementary teachers districtwide had five or fewer years of teaching experience, as compared to 38% of teachers statewide.

Table 3

Districtwide Comparison of Student and Teacher Race/Ethnicity

Race/Ethnicity	% of Students	% of Teachers
African American	8%	9%
Hispanic	41%	15%
White	47%	75%
American Indian	1%	<1%
Asian	<1%	<1%
Two or More Races	2%	<1%

Approximately 75% of the district's elementary students were classified as economically disadvantaged[1] and 30% classified as Limited English Proficient at the time of this research, both greater than statewide percentages, as 60% of students across the state were classified as economically disadvantaged and 20% classified as Limited English Proficient.

Recent local and statewide mathematics proficiency data, detailed within Table 4, highlight disparities amongst 3rd through 5th grade students as classified by race/ethnicity, socioeconomic status, and language. African-American students are depicted by state and district data as having the lowest percentage of mathematically proficient students across all grade levels. followed by the student group labeled economically disadvantaged or labeled Limited English Proficient (LEP). When comparing district-level data to state-

[1] The phrase *economically disadvantaged* is used by the state to classify students eligible for free or reduced lunch through the National School Lunch and Child Nutrition Program. Though *economically disadvantaged* is used in this study when referencing official state data, the phrases *students living in poverty* or *vulnerable students* are preferred, as this study denounces the use of deficit language.

level data, the district's African American and White student populations consistently received lower scores across all three grade levels.

Table 4

Local and State Percentages of Mathematically Proficient 3rd - 5th Grade Students

	3rd Grade		4th Grade		5th Grade	
Student Group	District	State	District	State	District	State
African American	50%	65%	55%	60%	50%	70%
Hispanic	75%	75%	65%	75%	70%	80%
White	75%	85%	65%	85%	70%	90%
Two or More Races	-	80%	80%	80%	90%	85%
Eco. Dis.	70%	70%	60%	70%	65%	75%
LEP	75%	75%	65%	70%	60%	75%

Note. Racial/Ethnic Groups with less than 10 students tested excluded.

Procedures

Teachers who previously took part in the CRME PD series were identified as potential study participants. After IRB approval was obtained, participants were verbally recruited to participate in the case study at the conclusion of the final PD week. They were also provided with a formal recruitment letter describing the nature and length of study participation, data collection activities, study withdrawal processes, and efforts to ensure confidentiality.

Several steps were taken to protect the identity of participants. Each was assigned a pseudonym to preserve anonymity, and any other identifying data, such as which elementary campus participants were originally from, was also masked. All video and audio recordings were immediately removed from within the district and taken to the researcher's home to be transcribed. Data was not returned to or stored anywhere within

the district. After transcriptions were complete, recordings were permanently deleted to remove any potential direct identifiers.

Data collection formally began the week after the conclusion of the PD series, beginning with artifacts collected from the PD, including video recordings of PD activities, participants' math autobiographies, and responses to pre-and post-PD questionnaires. Recordings were transcribed, and all data was entered into NVivo qualitative data analysis software for coding. Additionally, data were collected through classroom observations using a CRME Observation Protocol, then analyzed for evidence of culturally responsive or equity-based practices. Semi structured interviews were also conducted to learn more about the participants' understandings and use of equitable teaching practices, resulting in 11 weeks' worth of data collected. Data was continuously cross-referenced and coded as it was collected using NVivo qualitative data analysis software.

Description of Professional Development

As a mathematics instructional coach, my job was to collaborate with teachers through high-quality, sustained professional learning experiences to improve their practice, and subsequently, increase student achievement. The previously established collaborative nature of our teacher-coach relationship was extremely important, as it meant that we had already built up a certain level of trust, allowing me to easily immerse myself in the research setting. Over a period of five weeks, I facilitated a variety of professional learning experiences, outlined in Table 5, designed to maximize participant engagement, reflection, and transfer of learning in regards to culturally responsive math instruction. Each PD session began with a discussion of participant responses to the Math

Autobiography Prompt provided the previous week, followed by activities chosen to reflect the week's CRME Framework components.

Table 5

Outline of CRME Professional Development Activities

Week, CRME Framework Component(s)	Math Autobiography Prompt	Activities
Week 1: Teaching Math for Understanding, Depth of Knowledge/ Understanding	What was learning math like for you as a child in school? *(Did you always like it or not like it? Why/why not?)*	Build trust/establish norms Discuss achievement vs. opportunity gap with static and growth data
Week 2: Center Instruction on Students' Experiences, Cognitive Demand, Power and Participation, Academic Language Supports	What specific experiences affected your math learning? *(Did a particular teacher, family member, friend, situation, or math topic made you like/dislike math?)*	Read: *How I Learned to Take the SAT Like a Rich Kid* (Hernandez, 2017) *Math Literacy as a 21st Century Right* (McNaull, 2016) How were your math experiences similar/different from your students?
Week 3: Teaching Math for Understanding, Mathematical Discourse, Power and Participation	How was your math learning supported at home and/or in your community? *(How did family model math at home? Help with homework, etc.?)*	*The Case of Curry Green,* Multiplication representations activity (Aguirre et al., 2013) Reflect: What are your beliefs about math? Who is capable of doing it?
Week 4: Center Instruction on Students' Experiences, Cultural/Community-Based Funds of Knowledge, Social Justice	Were most students in your math classes from the same ethnicity, race, gender, linguistic, or socioeconomic background as you? *(How did they compare to the rest of the school?)*	Introduce CRMT Lesson Analysis Tool (TEACH MATH, 2012) Analysis of video: *Culturally Responsive Teaching* (Lancaster, 2015)
Week 5: Developing Students' Critical Consciousness With/About Mathematics, Cultural/Community-Based Funds of Knowledge, Social Justice	How has math affected your education/career path? *(Did course-taking patterns affect your opportunities? If so, how?)*	CRMT Lesson Analysis Tool Analysis of video lesson: *Math in Morocco* (Teaching Channel, 2018) Reflect on/discuss our time together and take any remaining questions

Professional development activities were purposefully aligned to Desimone and Pak's (2017) research-based conception of instructional coaching that includes (a) content focus, (b) active learning, (c) coherence, (d) sustained duration, and (e) collective

participation. All activities were *content-focused* in that they were specific to mathematics teaching and how to provide equitable instruction for diverse student populations. Teachers were provided with opportunities for *active learning*, as opposed to passively listening and receiving information, as they were regularly engaged in discussions, debates, and analyses throughout the PD, with lecture-based instruction used sparingly. The PD's content, goals and activities were *coherent* and aligned with district goals and objectives to provide quality PD and address inequities within the classroom. PD activities were ongoing for a *sustainable duration,* as they included not only the five one-hour scheduled group meetings, but also time reading, reflecting, writing math autobiographies, in-class observations and support, and engaging in informal conversations during the work week. Participants *collectively participated* in PD activities weekly to build an interactive learning community of Kindergarten through 5th grade mathematics teachers employed by the same district to learn and grow together.

Professional learning has proven to be most effective when concrete and explicitly linked to classroom content and practice (Aguirre & del Rosario Zavala, 2013; Desimone & Garet, 2015). However, culturally responsive teaching is contextual and specific to the settings in which it occurs. This is problematic, as culturally responsive frameworks are specific to the community context within which they are implemented. Gay (2013) explains,

> Culturally responsive teaching, in idea and action, emphasizes localism and contextual specificity. That is, it exemplifies the notion that instructional practices should be shaped by the sociocultural characteristics of the settings in which they occur, and the populations for whom they are designed (p. 63).

Regardless, teachers who have never viewed instruction through a lens of cultural responsiveness need PD facilitators to provide specific examples that connect to their students and content areas (2013). Therefore, participants were provided with the rubric components from TEACH MATH's (2012) CRMT Lesson Analysis Tool, along with detailed descriptions and flexible examples from which to build their own classroom approach. Table 6 provides the rubric components and descriptions to show specific culturally responsive practices that could be adapted across math classroom contexts.

Table 6

CRMT Lesson Analysis Tool Rubric Components (TEACH MATH, 2012)

Component	Description
Cognitive Demand	Level of student analysis/reasoning elicited by a lesson. High cognitive demand allows for reasoning and analysis of mathematical concepts. Low cognitive demand requires surface-level understanding and/or the recall of facts.
Depth of Knowledge and Student Understanding	Depth of student thinking/understanding within mathematical content of a lesson. Deep understanding means students make connections, compare/contrast, and explain/justify reasoning. Shallow understanding stays at the skills level.
Mathematical Discourse	Prevalence of opportunities for students to participate/discuss math in meaningful ways. High mathematical discourse includes and values communication from all learners. Low mathematical discourse includes minimal student-to-student communication.
Power and Participation	How widely student contributions are respected and valued. High levels of power and participation allow math authority to be shared between teacher and students, valuing all mathematical contributions. Minimal power and participation leaves math authority to the teacher, maintains status differences, and values students labeled "good" at math.
Academic Language Supports	Level of support for academic language development, particularly for ELLs. High levels of academic language support continuously embed language strategies to build meaning. Low levels of academic language support provide no scaffolds for new language acquisition, focus on "correct" pronunciation of English terms.
Funds of Knowledge, Social Justice	Relevance/authenticity to students' experiences and use of math to critique relevant social issues. High-relevance lessons use math as a pathway to transformation, while low-relevance lessons make no connections to critical contexts.

Note. Component descriptions adapted and summarized for this study from the original *CRMT Lesson Analysis Tool* rubric components created by TEACH MATH (2012).

Data Collection

Qualitative data was collected from a variety of sources, as a single source is rarely enough to provide the in-depth understanding of a case (Creswell, 2013). The inclusion of multiple data sources also allowed the researcher to triangulate the data, increasing the trustworthiness of research findings while also providing a fuller understanding of participants' experiences. Sources of data included participants' math autobiographies, video recordings of PD activities, audio recordings from semi structured interviews, participants' responses to open-ended pre- and post-PD questionnaires, classroom observations, field notes, and reflective memos recorded throughout data analysis.

Math autobiographies. Participants were provided with weekly writing prompts that required them to critically reflect on their previous mathematical experiences. According to Aguirre et al. (2013), "Because a mathematics teacher identity is, at least partly, rooted in a teacher's experiences as a mathematics learner, we must explore how those experiences may have been shaped, in turn, by race, class, gender, and language" (p. 28). Writing, reflecting, and discussing their personal experiences with math each week allowed participants the time and space to compare and contrast "their own experiences as mathematics learners, the influence of their past mathematics teachers, and their own conceptions about how mathematics should be taught" (Jackson & Jong, 2017, p. 67). Weekly writing prompts, adapted from Aguirre et al. (2013) included:

1. What was learning math like for you as a child in school? Did you always like it or not like it? Why/why not?

2. What specific experiences affected your mathematical learning? For example, did a particular teacher, family member, friend, situation, or math topic get you interested in, or make you dislike, math?
3. How was your mathematics learning supported at home and/or in your community? How did your parents/family model math for you at home (did they help with homework, etc.)?
4. Were most students in your math classes of the same ethnicity, race, gender, linguistic, or socioeconomic background as you? How did the student population in your math classes compare to the school population as a whole? Did this change at any point throughout your schooling?
5. How has math affected your career path? Did your course-taking patterns affect your opportunities? If so, in what ways?

Written reflections were discussed at the beginning of each PD session, allowing participants to collectively explore and make sense of ways their experiences contributed and shaped their beliefs about teaching mathematics, particularly for students from backgrounds different from their own.

PD video recordings. Using pre-recorded video can be beneficial to the observer, as they can be played and replayed for closer observation and more detailed data analysis (Glesne, 2015). All PD activities, with the exception of those completed during the first week, were video recorded using a Canon VIXIA HF R800 HD Flash Memory Camcorder. Audio recordings were used as backup recordings every week to limit the potential for data loss, such as audio interference from ambient noise or unanticipated malfunctions with camera technology. This was the case for the first week of PD

activities, as the camcorder battery was not fully charged, hindering video recording. Fortunately, complete data loss was avoided because of the supplemental audio recorded by a Yemeren digital voice recorder. All audio and video recordings were first transcribed by the transcription service iScribed.com, then I reviewed each one as I watched and/or listened to each PD session, correcting occasional mistakes made by the transcription service.

Open-ended pre- and post-PD questionnaires. Questionnaires allow data to be collected quickly and efficiently from multiple people simultaneously (Mertler, 2016). Participants responded to eight open-ended questions administered through the online survey platform SurveyMonkey before and after PD participation. Questions were adapted for this study from an existing survey instrument, the TEACH MATH Pre-service Teacher Survey (Turner et al., 2012), to create an appropriate and applicable pre- and post-intervention questionnaire that would. capture participants' language, understanding, and dispositions towards equity and access in math education.

The original 25-item TEACH MATH Pre-service Teacher Survey was developed to measure pre-service K – 6 math teachers' dispositions and understanding of delivering equitable math instruction through a teacher preparation course (Turner et al., 2012). The eight items selected for use in this study were chosen because of their alignment to specific components of the CRME Framework, ensuring alignment with the professional learning goals of the PD. While the original survey was intended for use with pre-service teachers with no teaching experience, this research studied elementary math teachers with a range of experience levels. Contextual differences between this research and the original study for which the TEACH MATH Pre-service Teacher Survey was created

made small changes to the phrasing of each item necessary in efforts to add specificity and clarification for participants. For example, original items referencing "elementary teachers" were changed to "mathematics teachers," as one of the nine participants was a self-contained teacher responsible for providing instruction in all subject areas instead of math only. This modification was important, as teachers who provide math instruction to multiple classes each day might interpret items differently than a self-contained teacher who teaches all content areas, applying the item to general teaching practices instead of those specific to mathematics.

Semi structured interviews. According to Glesne (2015), "Observation puts you on the trail of understandings that you infer from what you see, but you cannot, except through interviewing, get the actors' experiences, perceptions, and explanations" (p. 97). A semi structured interview protocol was designed to elicit participants' perspectives and interpretations of their PD experiences. Interview data were used to address the first research question by giving participants an opportunity to clarify and expand upon responses collected from autobiographical reflections and discussions to better understand their perceptions of how their prior sociocultural and mathematical experiences influenced their current practices teaching of mathematics. To address the second research question, interview data were used to expand upon questionnaire responses, providing insight into how PD participation may have influenced each participants' understanding of equity in math education.

Unscheduled informal interviews that occur naturally within a conversation are also useful sources of data (Gall, Gall, & Borg, 2015). In addition to formally scheduled interviews, informal interviews occurred on multiple occasions with individuals, as well

as with groups of participants. These informal conversations were just as valuable as the scheduled semi structured interviews, as they were natural occurrences in which participants were not responded to a series of questions, but equal contributors engaging in everyday conversation. Informal interviews were documented by taking notes during the conversation, as well as through reflective memos recorded immediately after each conversation.

Classroom observations. Classroom observations were conducted to observe how participant interacted with their students during a mathematics lesson, documenting the presence of equitable or inequitable teaching practices. My role as an instructional coach, which routinely requires me to observe and support classroom instruction in a nonevaluative manner, allowed me to assume the perspective of a nonparticipant observer to collect observation data. It is not unusual for students or teachers to see me walk in and out of their classrooms, allowing me to observe and record field notes with minimal disruption to the lesson flow. As recommended by Creswell (2013), an observation protocol was created to guide and record observations, questions, and reflections as they pertained to various CRME components (see Appendix C for full observation protocol). Based on the TEACHMATH (2012) CRMT Lesson Planning Tool, the protocol included observable indicators, examples, and non-examples for each CRMT component. Unfortunately, due to time constraints at the end of the school year, two participant classrooms were not observed within the weeks following PD participation.

Field notes and analytic memos. Field notes "provide practitioner-researchers the opportunity to maintain narrative accounts of their professional reflections on practice" (Mertler, 2016, p. 138). As Glesne (2015) suggests, field notes were both

analytic and descriptive, comprised of observer comments and impressions as well as rich, specific descriptions of experiences. Field notes were recorded throughout every stage of the research process – during PD activities, classroom observations, interviews, and while watching or listening to audio/video recordings. Reflective notes were also recorded while reviewing previously written field notes, documenting my own accounts of PD activities, interactions with participants, interpretations, and impressions throughout the study.

In addition to field notes, analytic memos were recorded throughout the coding and analysis processes. Saldaña (2016) advises, "Whenever anything related to and significant about the coding or analysis of data comes to mind, stop whatever you are doing and write a memo about it immediately. The goal is not to summarize the data but to reflect and expound upon them" (p. 45). These memos included lingering questions that were later included in semi structured interviews, as well as potential connections between PD sessions and participants.

Data Analysis Procedures

Qualitative data analysis requires the organizing of "what you have seen, heard, and read so you can figure out what you have learned and make sense of what you have experienced" (Glesne, 2015, p. 183). The collection and analysis of data often occurred simultaneously, a common approach to action research, as connections made during data analysis provided new directions that I was able to explore while still in the field. As a result, emergent understandings of participants' beliefs and attitudes influenced the revision of PD activities to address newly discovered areas for growth. NVivo qualitative data analysis program was used to assist with the management and analysis of data

(NVivo 12). Data were cross-referenced and grouped using NVivo to assist with a coding scheme based on the repetition of similar phrases, events, or observations to identify patterns for individuals, as well as the group as a whole, then analyzed using thematic analysis to locate patterns in the data. The accuracy of themes and patterns were validated through member checking, consulting with participants to confirm interpretations of findings throughout the analysis process (Saldaña, 2016).

To address the first research question, analysis began by watching and listening to all audio and video recordings of PD activities and participant interactions, as well as reading and coding transcriptions. Audio/video transcripts, math autobiographies, questionnaires, and field notes were coded using a values coding system to "explore cultural values and belief systems, identity, intrapersonal and interpersonal participant experiences and actions" (Saldaña, 2016, p. 132). Codes were then clustered into categories to identify connections with the research question and purpose. To address the second research question, analysis began by coding pre- and post-PD questionnaires to identify shifts in participants' attitudes or beliefs regarding CRME after PD participation. Video transcripts, interviews, math autobiographies, classroom observations, and field notes were then analyzed and triangulated to identify confirming or disconfirming evidence or specific events that acted as turning points, possibly causing the shift.

Trustworthiness

When considering validity for qualitative data, researchers are most often concerned with trustworthiness- the accuracy and reasonableness of the data collected (Mertler, 2016). Trustworthiness addresses the validity of qualitative research components by assessing the credibility, transferability, dependability, and confirmability

of the data (Glesne, 2015). This study established trustworthiness by applying multiple criteria to assess the research, including triangulation, thick description, clarification of researcher subjectivity, and member checking.

Triangulation enhances the trustworthiness of research findings by confirming consistency across multiple sources in order to build support for a certain perspective or theme (Creswell, 2013). Data sources were triangulated to ensure trustworthiness for both research questions addressed in this study. Triangulated sources included participant statements from PD recordings, interview responses, informal conversations and comments, autobiographical reflections, and questionnaire responses. Evidence confirmed through triangulation data sources also contributed to a rich, detailed description of this case, interconnecting the various details of participants' backgrounds with current experiences and beliefs.

Clarification of researcher subjectivity requires the researcher to openly acknowledge the influences of "past experiences, biases, prejudices, and orientations that have likely shaped the interpretation and approach to the study" (Creswell, 2013, p. 251). Without acknowledging subjectivity and positionality, a researcher could unknowingly make assumptions about participants and their experiences, leading to flawed interpretations and conclusions. According to Glesne (2015), "When you monitor your subjectivities and constantly challenge your assumptions, you are likely to realize moments when you project your identities and social positionings (e.g., working class, heterosexual) onto others" (p. 154). Efforts to avoid bias based on researcher subjectivity or positionality included frequent debriefs and conversations with participants about interpretations being made about their experiences, called member checking. Creswell

(2013) describes member checking as "taking data, analyses, interpretations, and conclusions back to the participants so that they can judge the accuracy and credibility of the account" (p. 252). Sharing data and drafts of the research study with participants affords them the opportunity to provide input and verify the researcher's interpretations from their own perspectives (Glesne, 2015). Member checks were performed at multiple points throughout the data collection and analyses processes to ensure participants were represented accurately, providing them with the opportunity to correct or clarify interpretations.

Though engagement in the field was extended for as long as possible, including classroom observations during summer school and continued communication with participants to ask clarifying questions, this study was limited to eleven weeks of collected data, including five PD weeks and six weeks of observations and interviews. Prolonged engagement in the field requires the researcher to spend extended amounts of time in the field conducting interviews, observations, and various other forms of interaction with participants (Glesne, 2015). As a school district employee and instructional coach for many of the study participants, I had previously established relationships with participants and the community, providing me with a deep understanding of the district and community contexts prior to conducting this research. This was an important aspect of my researcher positionality, as "knowing the context of the communities with which we engage as well as the length of time we have engaged with these communities is critical to establishing credibility" (Aguirre et al., 2017, p. 134). However, the time allotted to conducting this qualitative study was a limitation.

Chapter IV

Findings

This action research study explored two questions: (1) How do teachers' sociocultural and mathematical backgrounds and experiences influence their understanding and approach to equity and access in math education? and (2) How does professional development for CRME influence participants' understanding and approach to equitable and accessible math education? These research questions were addressed through the facilitation of a PD series designed to facilitate critical reflection and discussion of cultural responsiveness in mathematics teaching and learning through a variety of literature, activities, and discussion topics. Sources of data include video recordings of PD sessions, participants' autobiographical reflections, responses to open-ended pre- and post-intervention questionnaires, semi structured interviews, classroom observations, and researcher's field notes and memos. Data was analyzed with the support of NVivo qualitative data analysis software to identify important themes and patterns as they emerged for individual participants and the group as a whole.

This chapter review the evidence and research findings that resulted from this analysis. First, the research setting and participants are described to provide the overall context of the study. A detailed description of research findings and themes identified across participants will then be revealed. Finally, thematic changes in participants' responses to pre- and post-PD questionnaire responses will be presented and triangulated with additional sources of data, including participants' autobiographical reflections, interviews, and recordings from PD activities, to corroborate the findings.

District Setting

This study was conducted in a midsize rural school district serving between 5,000 and 6,000 students and employing between 300 and 400 teachers. Enrollment in student programs included 3% of the population enrolled in the Gifted and Talented (GT) program, 9% receiving special education services, 20% English Learners, and 70% labeled economically disadvantaged by the state because of their participation in the Free and Reduced Lunch Program. The three largest student groups by race/ethnicity were White students representing 47% of the population, Hispanic students representing 42%, and African American students representing 8%. Consistent with recent reports of demographics in U.S. education (Goldenberg, 2014), there is a noticeable discrepancy between teacher and student racial/ethnic demographic groups, as the teacher group breakdown included 75% White, 15% Hispanic, and 10% African American teachers,

While stagnant assessment data presents gaps in achievement as told by a single data point, usually standardized assessment scores, measures of student progress and can reveal growth over time. This kind of data is intended to help stakeholders determine if they are narrowing the gaps in scores between different student groups. In this district, math achievement scores across all elementary grade levels fell below state averages, with significant gaps between racial/ethnic groups and socioeconomic groups. However, the state also provides a measure of students' progress from year to year, categorizing students as demonstrating less than one year's growth, about one full year's growth, or accelerated growth. Table 7 provides a summary of districtwide data across student groups.

Table 7

Student Progress in Mathematics from 4th-5th Grade and 3rd-4th Grade

Current Grade Level	Student Group	Growth from Previous Year's Test Score: Limited <1 year	Expected ~1 year	Accelerated >1 year
5th Grade	African American	50%	40%	10%
	Hispanic	45%	45%	10%
	White	40%	40%	20%
	Economically Dis.	45%	40%	15%
	LEP	45%	45%	10%
	Special Education	40%	45%	15%
4th Grade	African American	57%	40%	3%
	Hispanic	50%	35%	15%
	White	60%	25%	15%
	Economically Dis.	55%	30%	15%
	LEP	45%	35%	20%
	Special Education	65%	14%	21%

Note. Student groups with less than 10 students tested excluded.

5th grade progress data indicates that the percentage of students gaining approximately one year's growth is similar across all student groups, about 40-45%. However, the percentage of White students with more than a year's gain in scores is twice the percent of any other race/ethnic-based group, while the African American student group had the highest rate of students with limited growth. This indicates that the gap established the previous school year is actually getting wider.

In 4th grade, 21% of students enrolled in special education demonstrated more than one year of growth, more than any other measured student group. However, this group also had the highest percentage of students with limited growth with 65% of students not showing enough progress from the previous year's test score.

Participant Overview. Nine elementary math teachers from across the district volunteered to participate in this study. Consistent with district- and nationwide teacher demographics, most participants identified as White females, as the summary of participants' personal and professional profiles in Table 8 depicts. Participants averaged approximately six years of teaching experience with an average of three years employed by the district, both lower than the overall district averages.

Table 8

Summary of Participant Profiles

Participant	Gender	Age Range	Race/ Ethnicity	Grade Level	Years of Experience
Christine	Female	40 – 44	White	3rd – 5th	1 – 3 years
Victor	Male	34 – 39	Hispanic	3rd – 5th	4 – 6 years
Ava	Female	25 – 29	White	3rd – 5th	4 – 6 years
Elena	Female	35 – 39	Hispanic	K – 2nd	7 – 9 years
Julia	Female	45 – 49	White	3rd – 5th	10+ years
Sofia	Female	30 – 34	White	3rd – 5th	7 – 9 years
Evelyn	Female	25 – 29	White	3rd – 5th	4 – 6 years
Karen	Female	25 – 29	White	3rd – 5th	1 – 3 years
Dorothy	Female	25 – 29	White	3rd – 5th	1 – 3 years

Data Presentation and Analysis for Research Question 1

Data collected from study participants' math autobiographies, PD video transcripts, interview transcripts, classroom observations, researcher's field notes, and questionnaire responses prior to PD participation were triangulated to ensure consistency across sources of data. Findings indicate a relationship between participants' sociocultural backgrounds, mathematical experiences, and understanding of equitable and accessible mathematics education. As Figure 2 illustrates, teachers' beliefs and attitudes

towards sociocultural differences and the purpose of education were informed by their own sociocultural background experiences. Beliefs and attitudes towards mathematical understanding were shaped by their previous experiences as learners and teachers of mathematics. Both areas informed how they understood and approached equity and access within their own practice. Though it is not possible to account for every potential contributor to a person's understanding of equity, participants' environmental contexts, such as the teaching context, school and classroom contexts, and PD context can influence how they engage in the experience (Wager & Foote, 2013).

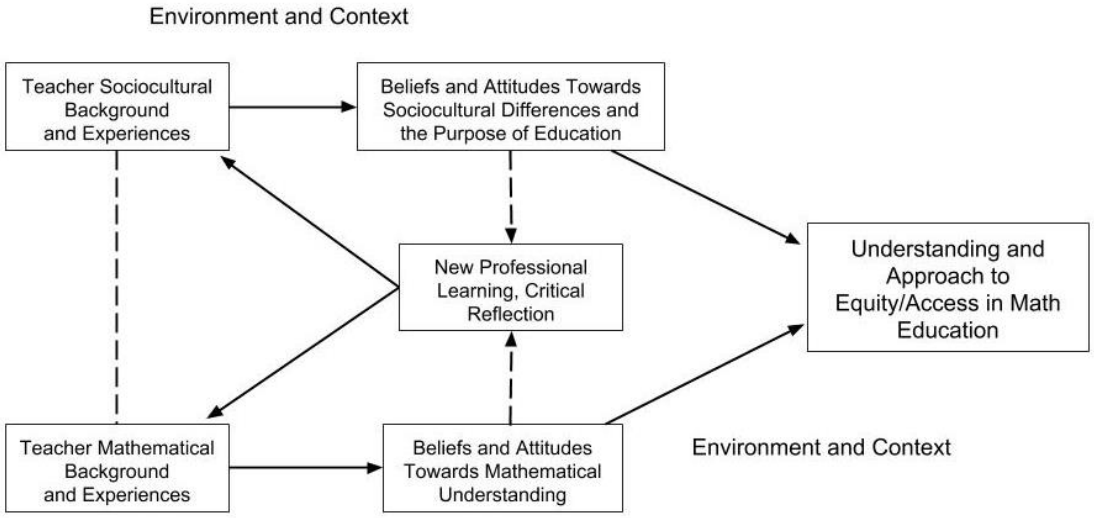

Figure 2. Conceptual model illustrating PD's effect on equity/access in math education.

Additionally, participants sociocultural and mathematical beliefs and attitudes influenced how they perceived and participated within the PD series, making sense of new professional learning. This new learning experience, as well as any changes in their belief systems as a result of critical reflection, became yet another sociocultural and mathematical experience that teachers added to their background knowledge.

Sociocultural and mathematical backgrounds, experiences, and understandings of equity and access in math education. This section describes each participant's account of his or her mathematical and sociocultural background and experiences as they related to his or her understanding of equity and access in math education. Any data collected during or after new professional learning occurred were not included for this section of analysis, as the intent of the research question was to understand participants' experiences prior to PD participation. Member checking was used on multiple occasions throughout the research process to confirm the accuracy of interpretations made based on participants' statements or actions. After considering the connections made between participants' experiences and their understandings of equity and access, themes identified across participants will be discussed.

Victor. Victor, a Hispanic male between the ages of 35 and 39, taught bilingual math and science for the school district for 4 – 6 years. Raised in Mexico City, he described his family as "uninvolved" with his schooling, but not because they did not care – "Only because I was making good grades, meaning they never had to help me with my homework. But I knew that if anything didn't go the way it was supposed to, then I would be grounded." His parents made sure he had opportunities to participate in enriching activities outside of the school setting, such as learning to speak English and play classical music. He seemed to have found these activities to be worthwhile and valuable, as he was observed playing classical music while his students work independently on an assignment during an observation of his classroom, taking time to explain the historical context of the music and its composer. On another occasion, he began a lesson by projecting famous architecture from Rome and allowing students to ask

questions about it, attempting to enrich their educational experiences beyond those required by state standards.

Victor remembered himself as a confident, and at times boastful, math student– "I liked math so much because I was good at it, and I wanted to let everybody know it. I think that's the motivation for most of our children – if it comes easily, they want to show it." It was not until he enrolled in his first college math class that the coursework began to challenge him. He recalled,

> Looking back, I know that I didn't understand complex ideas back then, but the teaching methodology required only, or mostly, arithmetic [computation]. In college, I started to perform poorly in my [math] courses- calculus, matrices, geometry, and so on. I had to adjust to a new way of thinking very fast. I think in those two years of struggling, I changed how I approached math. Instead of just executing exercises, I began really understanding concepts, always approaching [problems] with an open mind. That's what helped me throughout the rest of my mathematics learning.

His appreciation for deep mathematical understanding was also evident in his instructional approach, as he desired for his students to become problem solvers, able to approach challenges from multiple angles. "Maybe you don't have to memorize anything," he explained. "Maybe next time, just look at with fresh eyes. That's what I always tell my kids, always try to find ten ways to solve it – pictorial, standard or whatever – and try to solve it." From his perspective, the problem-solving skills students develop through learning mathematics could equip them to confidently approach any situation in life.

Though he had a passion for teaching mathematics, Victor's statements about his students, all native Spanish-speakers with approximately 90% considered economically disadvantaged, often contained deficit-oriented language, such as when he referred to his students as "lazy thinkers" who lacked the motivation required to attempt challenging tasks or apply critical thinking. He explained, "If they're not told specifically to do something, or to come up with something, or think of something, they just won't." His low expectations for student performance parallel those for his students' parents and local community. He believed that they did not value education, especially those that were living in poverty – "I think parents are used to the idea of the family economy being week-to-week or day-to-day, and they don't see education as a tool that can help them get past that. Education is a long-term investment, so they prefer to have the kids working at home or helping out in minor businesses." He also recalled that in Mexico City, being bilingual was considered a status symbol because it was a choice people made to become. However, in this school community, it is viewed as a deficit because bilingual students are associated with low-income households.

Victor attributed much of his own success to his upbringing and the high expectations communicated by his parents. As a child, the values instilled through his parents' high expectations and regard for authority were apparent during a discussion regarding the role of the local community in learning of mathematics –

> Students feed off their community. If the community is not challenging as a whole then families are not socially guided to perform at the critical level required for students to excel in every educational aspect. If the community sets low standards for performance in education, arts, order, discipline, and sports, then the students

> are aware of what's expected of them and adjust [lower] their own expectations and drive to perform.

He viewed the school community in which he worked, including his students' parents, as holding different values than the community he grew up in. He believed they held low expectations for their children and attributed students' lack of success and low motivation to their values. During a group discussion, he stated, "I think the community is what drives the students' performance more than anything else, even schools…I think our performance as a school district reflects the community we live in." "Does that mean that we *know* our students are going to be low-performing because of the community they come from?" I asked. He simply responded, "Yes." In his opinion, poor performance and low levels of motivation were attributable to conditions outside of the school environment and outside of his control.

Sofia. Sofia, a White 30 – 34-year-old female teacher, was born and raised within the local community she served, dedicating her teaching career thus far to her hometown. As a child, Sofia was a self-proclaimed "math nerd" who enjoyed challenges and looked forward to attending her advanced math classes at school. Thought she perceived her family to be supportive of her education and willing to help whenever needed, she rarely required their assistance, believing that high school math was "a little over their heads." She was always an independent learner and was intrinsically motivated to work hard and be successful.

Though she had spent a vast majority of her life within the rural community and raised her own children there, she did not understand that her own sociocultural

experiences were not the norm for the rest of her community until after she began her career in education –

> I grew up in this town, lived here my entire life. I never realized how blessed I was in this community until I took my students on a field trip during my first year of teaching. My own children, who were much younger than my students at the time, had already been to Disney World and travelled outside the state several times. They've been all these places, right? While we were on the bus driving just a few towns away, I realized that most [of my students] had never left our city limits. I'm not kidding, 75% of them had their faces glued to the windows in awe. It would be one thing if we were driving through the city and they saw a skyscraper for the first time, but we were not that far from home!

Though the experience gave her they opportunity to see her community from another perspective, Sofia had a tendency to utilize deficit-oriented language in regards to what she perceived to be a lack of background knowledge from her bilingual students, 84% of whom were labeled economically disadvantaged by the state. She also believing that knowing students' backgrounds could provide insight into "whether or not school academics are important at home" and whether or not her students' parents valued their education. When asked how she knew that the parents did not value their child's school experiences, she gave examples such as never returning phone calls, not showing up to parent-teacher conferences, and never checking their school work. "Generally speaking, successful students are those who have parents behind them, encouraging and aiding and reminding of the importance," she said.

According to Gorski (2016b), "When it comes to issues surrounding poverty and economic justice, the preparation of teachers must be first and foremost an ideological endeavor, focused on adjusting fundamental understandings not only about the educational outcome disparities but also about poverty itself" (p. 379). Many of Sofia's statements concerning children from low-income families aligned with Gorski's (2008) myths based on stereotypes of students from poverty, such as the belief that low-income parents are unmotivated or lazy, and that they are uninvolved in their child's education because they do not value education. However, similar to Victor's conflicting statements, Sofia also had a mixture of resource- and deficit-oriented statements about her students, such as encouraging her to students to communicate and explain their understanding in their own words, allowing them to "use new math vocabulary and concepts and their own definitions interchangeably" to participate in meaningful mathematical discourse. She wrote about the high expectations she held for her students – "My students will be doing more than simply solving an equation; they will be able to apply their knowledge to more complex situations. Student can write problems that relate to their own experiences for their friends to solve, then be able to turn around and explain it in their own words." – and worked to create an environment supportive of the needs of her English Language Learners.

Evelyn. Evelyn was a White female between 25 and 29 years old. Though she was new to the district, she had between four and six years of teaching experience prior to joining the staff. Her childhood was spent in a rural town so small that her high school graduating class consisted of only 30 students. In her opinion, the community had little to no racial diversity within its population. She explained,

> I don't mean for this to come off wrong, but I had never even met an African American person until I went to college. It felt like a culture shock because they had a different...I felt like they had different mannerisms and patterns of talking than I was used to. I'd never been around [people who did not look like me] before in my whole life. But our parents taught us that all people were made equally, so it's not like I was raised in a racist atmosphere or anything. I just never had that exposure before.

Since Evelyn was raised in a low-income household herself, she felt she could identify with the struggles that 67% of her 4th graders experienced growing up in low income households in a rural community – "Other [nonrural] areas have these commercial tutoring centers that kids can go to for help with schoolwork, but it's just not really that common [in rural areas]. If you want help outside of school, your parents *might* be able to help you, but there are no other options." Evelyn tried to offer extra tutorials outside of school hours for her students but discovered that most of them took the bus and did not have access to transportation outside of regular school hours. This particular discussion reminded Evelyn of a time when she had desired to enroll in a SAT preparation course in high school with some of her classmates outside of the regular school day, but her family did not have the ability to pay for it. She felt fortunate that her high school was able to offer dual-credit courses during school hours, allowing her to graduate with a full semester of college credits.

As a student, Evelyn enjoyed her mathematics classes, stating that math always seemed to be easy for her. She considered her parents to be supportive of her schooling, but they were generally uninvolved since she never asked for help with schoolwork and

made good grades. She believed they demonstrated their support by teaching her valuable social skills and how to show respect towards others. “I never questioned adults because that's disrespectful. I was taught to always be respectful and follow whatever they told me to do with a positive attitude, even if I didn’t want to,” she recalled. Similar to the views expressed by Victor and Sofia, Evelyn expressed the belief that many of her students living in poverty had unsupportive parents. However, her perspective differed slightly in that she felt sorry for them. While reflecting on the role a family should play in the learning of mathematics, she wrote, “Some children are in tough environments where they're in survival mode, so they may not focus on mathematics as much as a student who is in a nurturing environment and has support.”

Evelyn’s pre-questionnaire responses indicated an inclination towards procedural mathematics with little application outside of the classroom. She wrote that “to ‘know’ math means that you understand the concepts and how to arrive at an answer by understanding the method to get there.” Field notes from classroom observations also revealed an emphasis on mathematical procedures without real-world connections. Researcher field notes read, “Any mathematical application or word problem is presented as it would be on a standardized assessment in which they use test taking strategies instead of encouraging students to discuss and understand what the problem says/is asking.”

Elena. Elena was a Hispanic female teacher between 35 and 39 years old. She worked as a bilingual teacher in a self-contained classroom with almost a decade of experience working with English Language Learners. Originally from Venezuela, Elena’s description of her childhood and family expectations were unique in comparison to the

other participants. First, her parents held very different academic expectations for her than they did for her brother. “I'm trying to remember my parents ever helping me with math. I remember my parents placing my youngest brother on mental math activities, and word problems, but never me” she told us. “There was a lot of *machismo* out there [in Venezuela].” Though it was difficult, she felt that her family circumstances pushed her to become a very independent and self-sufficient learner who worked hard throughout her education so she could attend a good college. Elena recalled instances of gender bias by the parents of some of her female students during parent conferences – “They all depend on Mom. There are multiple kids and Mom needs to be there cooking, working, doing most of the household chores, plus probably having a job. Even if my girls have the ambition, it's harder for them because they are being held to the expectations that their families have for them.”

Elena confessed to our PD group that she often felt isolated from her bilingual colleagues. She explained this sentiment during a group discussion concerning sociocultural identity –

> I started writing down Hispanic, but I crossed it out and I put Venezuelan, because as a race, as a Hispanic race, I *should* belong with them [other bilingual teachers]. We *should* be the same group, and we are not. There's a huge cultural difference, and it has more to do with the fact that I am Venezuelan and they are mostly from Mexico, and that creates a huge cultural gap. It’s like comparing an English guy and an American guy – they speak the same language, but they are still very different.

She felt that she was supposed to feel a sense of community when surrounded by other bilingual teachers, yet she did not.

As a student, Elena felt comfortable with mathematics, recalling that high school math was actually easier for her than elementary math because it was more focused on mathematical applications and less on memorization and repetitive practice. Her biggest struggle with mathematical content understanding did not occur until after she began her teaching career in the U.S. and had to learn how another country approached mathematics in a very different way than what she was accustomed to. But after exploring the more concrete, conceptual methodology, she realized that for the first time, she understood the "math behind the math – I had no idea what I was doing. For instance, I never understood the 'why' behind, the regrouping process for subtraction. I literally did not understand it until I had to teach it here in second grade."

Elena strived to help her students, especially her female students, be successful in math by making conceptual connections to whatever existing knowledge they presented. "When they can explain using their own examples, I know they get it," she wrote. Elena acknowledged that the 96% of her students labeled economically disadvantaged, as they participate in the Free and Reduced Lunch Program, face unique challenges that she has never experienced, and as a result, have less access to mathematical opportunities than some of their schoolmates. Elena viewed students' families and communities as essential resources for learning that she could use to help teach math for true understanding – "I think that by making math relevant to them, I can have an impact on how they can see the usefulness of math, hence the importance it has for their education."

Julia. Julia was a White female teacher between the ages of 45 and 49. Though she taught elementary math at the time of this study, she had more than 20 years of classroom experience ranging from Kindergarten to 8th grade. As a child, her parents set the expectation early that school was important – "It wasn't an option, you just had to do well in school and that was the priority. But with that being said, I don't remember my parents ever saying, 'Do you have homework today? Get it done.' That was the expectation." Though she felt her parents had high expectations for her academically and behaviorally, they were not directly involved in her homework or classes. "Nobody ever had to help me," she said. "I was a musician and a whizz at math, so that's what I did, and my parents – the whole family supported me."

Julia loved mathematics throughout all stages of her education – "It's always been my favorite subject, so it came easily all the way though. I'm a number nerd." She believed that to truly understand mathematics, one needs to know *how* to solve a problem, *why* it is solved a particular way, and be able to explain his or her understanding using accurate mathematical vocabulary. She placed an emphasis on procedural mathematics while making connections to other mathematical representations and vocabulary. However, connections were not necessarily made outside of the classroom.

Julia and her sister grew up on the Free and Reduced Lunch Program due to their household income, just like 65% of her students, but it "wasn't really a big deal." When asked how her sociocultural background and experiences impacted her teaching, she adamantly stated, "My sociocultural background does not inform my decisions about creating and delivering math lessons. Sure, I put my own twist on my lessons, but this involves my personal taste and personality rather than my sociocultural identity." She

insisted many times that she "does not see color," both when speaking of her own personal experiences and her approach to working with diverse student populations. "I went to school with all different races, ethnicities, whatever, and I don't ever remember saying, 'Oh, I'm the only white person or that's the only black person.'," she said. "[My students] may see race as part of their culture at home, but it doesn't have to be a part of their culture at school. It doesn't have to be. I don't see color," she insisted. At one point, Julia contradicted her self-proclaimed color blindness when describing the population of her high school. Her family moved to a new town shortly before she began 9th grade, forcing her to start high school in a new location. "I went to an all-white high school at that point, and that was a culture shock for me. I was like, 'Where is everybody else?'"

Julia often used deficit-oriented statements when discussing her students living in poverty. During one of our PD activities, participants were asked to identify a student they perceived to be weak in mathematics. Later in the discussion, they were asked to write what they knew about their chosen student's sociocultural background, then reflect on ways they were alike or different from their own background experiences. When it was Julia's turn to share, she stated,

> With my particular student, her attendance is horrible. She's Caucasian. She's from a family of seven. Some are half [-siblings], some are step [-siblings], I'm not sure, but there are seven kids that live there. I met the mom several times, and I honestly think that the reason her attendance is poor and her grades are not good is because the mom is literally just trying to survive. I think that's the priority. She's just trying to keep their head above water and it's... I think it's sad, but I do think that's what's going on.

Consistent with Gorski's (2008) myth about the culture of poverty, Julia believed that this student was less capable of achieving at high levels because she was living in poverty, where school is not the priority. She stated, "I do think that the parent's view on academics, or school, or math in particular, is part of their culture. That's what I think."

Dorothy. Dorothy was a White female between 25 and 29 years old with approximately three years of teaching experience. Her parents were very involved in her schooling for as long as she could remember. She credited her mother multiple times for being her source of strength and motivation to continue working hard, even when she lacked confidence in herself –

> My parents were really supportive and did whatever they could to help me in any way possible. It's funny, I feel like you always hear that your childhood shapes who you are. I've reflected, and I I feel like I work harder now because of my parents and how much they supported me. Every day, my mom would pick us up from school and we would go home, and we would start working on our homework while she'd be cooking dinner and talking to us, helping us work through our [homework] problems, and we had that routine. Then she would always check and make sure our work was good, and if I had problems she would talk to my teacher, she would take me to school early, or let me stay late. I went to a tutoring center, too, but she gave me lots of pep talks and I feel that if it wasn't for her pushing me and making sure that I'm doing what I'm supposed to do, I wouldn't be working as hard as I do today.

She highly valued the level of support she received from her parents. Additionally, she placed a large emphasis on the value of hard work, particularly in school, where she

spoke of herself as a "struggler" on multiple occasions – "I just think about my history and knowing that I *always* struggled and just knowing that math was not… I just had to work so hard at school."

Dorothy believed that she "just wasn't strong in math." While considering how her prior struggles with learning mathematics herself affected her teaching approach – "I always struggled with math, and with school in general. I had to work so hard at school, and now, I don't want kids to struggle." She was able to recall one positive experience in a mathematics class while she was in college. She had one particularly supportive and patient math teacher who made her feel that she was actually capable of understanding math. This experience was significant enough that it influenced her to pursue a career as a math teacher so she could help kids who struggled with math as much as she did.

While reflecting on reasons why knowledge about students' sociocultural backgrounds was important for learning mathematics, Dorothy wrote, "Most of the time, my students don't have a lot of background knowledge. So, I try to dig deep and make sure that my lessons connect to the students and to real world situations." While she did make an attempt to connect to students' "real world situations," she did not perceive their sociocultural experiences as important resources for learning, but as deficiencies, stating that some kids did not have "a lot of background knowledge" to bring into the classroom. According to Milner (2012b), "Due to a deficit mindset, educators sometimes believe they are actually doing students a favor by not developing challenging learning opportunities (p. 707). Dorothy's statements often reflected this sentiment, as she would often "go easy" on her vulnerable students, making up 84% of her student population, out of pity because she felt sorry for them. Her beliefs about students' capabilities and low

expectations for performance continued to be evident in subsequent weeks, such as a comment she made referencing her belief that students from low-income households present more behavior and academic problems than other students – "Their parents don't know how to support them, or they are so busy working trying to support the family that the kids are kind of left. I have quite a few kids that are just kind of left behind." Her perspective reinforced stereotypes of low-income families as not caring about or prioritizing their child's education, though research has shown that this is simply not true (Gorski, 2008).

Karen. Karen was a White female between 25 and 29 years old. This was her second year in education. From her perspective, she was raised in what she thought to be a "typical" middle-class suburban community. Her parents were very supportive of her education and involved in her schoolwork – "As long as I gave a 100% and did the best I could, they were happy, and they helped me [with my schoolwork] at home." Similar to Dorothy's experience, Karen highly valued the support and involvement from her family. The connection to her current practice became clear when she described her students, whom she perceived to be academically unsuccessful because of deficient parent involvement with school – "I've had parents not answer my phone calls or not show up to [parent-teacher] conferences after I reach out to them multiple times with concern for their child. I feel this means they do not see the value in education or collaborating with me."

Karen's most impactful experiences with learning mathematics were the struggles she experienced. She explained,

> In third grade, [I started at a new school where] we were on completely different math content. I didn't know what multiplication was, I didn't even - I've never even heard of it and the kids around me already knew it. So, they would pull my brother and I [for extra help] up until sixth grade when we went to a private school, so they were - they're a little more advanced. We did better, but still were not where we wanted to be, so we repeated sixth grade. After that, it just clicked.

Her difficulties with math returned again in college, and from that point on, just "never jived."

Karen taught one class of students considered to be Gifted and Talented (GT) students and one regular class. Her GT students came from backgrounds that were much closer to her own – they were almost all white, and about 75% were from a middle-class household. "My students who are not GT seem to be a lower-class background and Hispanic," she observed. She often classified her students as either "GT kids" or "Low Kids," pointing to differences in their work ethic and motivation, believing their families were lazy and incapable of doing more – "As life goes on hopefully they are going to find that encouragement to just do better than what maybe their parents are doing or to realize there's more than just [this small rural town]." Milner (2012b) called this the "myth of meritocracy" in which teachers believe that hard work is rewarded with success without recognizing the systemic barriers and inequitable access to opportunities to learn.

Christine. Christine was a White female between 40 and 44 years old in her second year working in education. Raised in a low-income household, she generally described her family as unsupportive and uninvolved with her education. Her father, an engineer, was "not very nice," especially to her mother, as he thought she was "not smart enough to do math." Christine could only recall one instance when a family member, her father, attempted to help her with her school work – "He would say, 'No that's not correct,' and then I would have to do it again. There was no explanation, just 'Do it again until you got it right,' and that was the lesson – keep doing it, keep doing it." Though she strongly disagreed with his parenting style and methods, she did believe that it pushed her to that it helped her to become the independent person that she is today.

As a student, she struggled in her math classes – "Math did not come easily to me...You either learned standard algorithm, or you didn't. There were no manipulatives or models – there was nothing, and so I struggled tremendously." It was not until after she got married that her husband's job took them overseas for extended periods of time, giving her the opportunity to work as an administrator for an international school, that she realized there was more to mathematical understanding than rote memorization. Other countries used approaches to learning mathematics that were much more conceptual than the "old school" methods she was taught:

> I started working in the international schools [as an administrator] and saw how other countries taught their children. I saw the models and the manipulatives and I thought, 'Well, that makes sense.' I guess I'm just more pictorial in how I learn, more hands on. So, I decided at that point that I wanted to help others that struggled just like I did.

As a result, she then believed that "math is the one common language that spans our globe." Her belief in the power of mathematical connections was apparent when she spoke about her own approach to teaching for understanding – "The student can apply the knowledge to logically solve problems of any realistic level. They can build their knowledge. Opposite of this is rote memorization that gives the ability to only solves one specific problem. Students are unable to work beyond a set scope."

Christine had trouble describing her own sociocultural identity – "It's difficult. I think what you want to portray is sometimes very different than what people see." She consciously tried to remove her own "stereotypical instincts" about students' backgrounds when planning or delivering math instruction in an effort to make the lessons not about her, but about her students. While she attempted to remove her stereotypical instincts and not make lessons about her own identity, Christine also insisted that race played no part in the learning or teaching of mathematics. This colorblind stance amongst white preservice and working teachers has been identified across multiple research findings (Jackson & Jong, 2017), as teachers from the racial majority are often concerned that by acknowledging racial differences in students, they would be promoting stereotypical thinking. "I don't see color, I see students in my classroom," she said. "Yes, I want to reach them and their backgrounds and all of that. But I'm not going to put them in a group to teach them differently."

Ava. Ava, a White female between 25 and 29 years old, had five years of elementary math teaching experience. As the youngest of six children in a middle-class family, there was always someone available when she needed help with her schoolwork, even though both of her parents worked at night. Ava was very hesitant to discuss the

sociocultural backgrounds and experiences of both her students and her own, particularly when the conversation was focused on race. "This makes me feel uncomfortable. I don't know how to answer this," she said during the first PD week. After considering the possibility of no longer participating in the PD series, I was concerned that she would not come back after that first week, but when she did return, she eventually chose to come back the second week and continue per participation.

When asked about her own experiences, she recalled her family as supportive and usually involved with her education –

> Both my parents worked nights. I would come home after practice and then work on my homework, but I was the youngest of six and so I always had someone older than me to help me if I needed it…so my parents didn't necessarily help me, but my siblings did. When I got into high school, and in my first year in college when I was in a math remediation class, my dad – he had graduated with a civil engineering degree from Texas Tech – helped me study a lot more with math.

She valued this experience, as she also believed that students who did not have parents or a community involved in their learning were more likely to struggle in school. Slowly, Ava became more comfortable and began to contribute to discussions about student backgrounds in terms of social class, but still remained quiet when the conversation turned to race. Though she made few comments herself, she would sometimes nod or state agreement when other participants would attribute students' low motivation or achievement on a lack of support from the community or family.

Ava's experiences with learning mathematics were a mix of positive and negative experiences beginning at a young age –

> When I was in elementary, it was easier for me, although all I really remember is doing problems out of the textbook. As I got into junior high in high school, it got harder. High school, I always had a tutor. Then my first year in college, I was in a remedial math course before I got to take the actual math class for credit. As I got older, it was just harder for me to grasp things.

Though she always knew that she wanted to be a teacher, Ava's interest in math itself did not develop until she began her first teaching assignment. "My very first year I was self-contained, so I taught everything," she recalled. "I think that's kind of when I grew to love math the most. It's more fun." Reflective of her own experiences learning mathematics, her teaching approach aligned with the belief that students need hands-on experiences and opportunities to collaborate with their peers to make new mathematical connections.

Influence of sociocultural backgrounds and experiences across participants. The first research question investigated how teachers' sociocultural and mathematical backgrounds influenced their understanding of equity and access in mathematics education. According to Milner (2012b), "At the heart of what is and is not emphasized in the curriculum of educational practices is both teacher and student identity—who teachers and students are and how they represent their worldview to others" (p. 700). Awareness of one's own beliefs and attitudes towards math education, grounded in his or her personal background and experiences, is critical to understanding other perspectives and adopting a culturally responsive approach to teaching mathematics.

Teachers' sociocultural identities are constructed from the various lived experiences as they contribute to their beliefs, attitudes, and perceptions of how the world

works and what is considered "normal". Three broad themes, summarized in Table 9, emerged across participants' beliefs and attitudes towards education and learning as influenced by their sociocultural backgrounds and experiences – (a) the roles of, and connections between, race and culture in education, (b) meritocracy and the value of hard work, and (c) interpretations of family and community support and involvement.

Table 9

Sociocultural Categories and Codes Identified by Thematic Analysis of Qualitative Data

Category	Code	Sources of Qualitative Data	# Participants	Frequency of Code
Race and Culture (40)	Multicultural Experience *(Background/Experience)*	PD Weeks 2, 3, 4, and 5; Interviews; Field Notes; Memos	5	21
	Color Blindness *(Belief/Attitude)*	Pre-PD Questionnaire; PD Weeks 3 and 5; Interviews; Field Notes; Memos	5	19
Meritocracy (57)	I worked hard to succeed *(Background/Experience)*	PD Weeks 2, 3, and 5; Math Autobiographies; Interviews; Memos	7	17
	Success as directly proportional to hard work *(Belief/Attitude)*	PD Weeks 2, 3, and 4; Interviews; Field Notes	7	9
	Unsuccessful students do not work or try hard enough *(Approach to Equity/Access)*	PD Weeks 2, 3, and 4; Interviews; Field Notes; Memos	7	31
Family and Community Support/ Involvement (78)	High Expectation, High Involvement *(Background/Experience)*	PD Weeks 2 and 3; Math Autobiographies; Interviews; Field Notes; Memos	3	13
	High Expectations, Low Involvement *(Background/Experience)*	PD Week 3; Math Autobiographies; Interviews	4	5
	No Involvement *(Background/Experience)*	PD Week 3	2	3
	Low expectations from community *(Belief/Attitude)*	Pre-PD Questionnaire; PD Weeks 2, 4, and 5; Interviews Field Notes; Memos	8	18
	Parents do not care *(Belief/Attitude)*	Pre-PD Questionnaire; PD Weeks 2, 3, and 4; Interviews; Memos	9	39

The roles of, and connections between, race and culture in education.

Experiences with, and understanding of, racially diverse populations varied between participants. For example, Victor, raised in Mexico City, had several opportunities to travel outside of the country and engage with people from a variety of backgrounds. He was very aware of the sociocultural similarities amongst not only study participants, but also the district staff as a whole, believing that discussions concerning sociocultural identities would be "much more interesting in a community that was more diverse." Evelyn, on the other hand, did not have the opportunity to travel as much and grew up in a small, rural town in which 94% of students were white and less than 1% were not native English speakers. "It's way different teaching here [than where she grew up], with there being so much diversity. It's just different." Because of their vastly different experiences with diversity, Victor and Evelyn each had a different perspective on the diversity of the school district and its staff.

Similar to findings uncovered by Jackson and Jong (2017), participants were uncomfortable discussing matters of racial inequities within the school system, but openly discussed differences in socioeconomic status (Jackson & Jong, 2017). This was evident most often when participants noted that their students "didn't have a lot of background knowledge" on a pre-PD questionnaire response, that they are "pulled down by the expectations that their families have for them" during PD discussions, or a general expression of pity that allowed teachers to lower their expectations for their most vulnerable students during an interview.

Julia, Victor, and Christine strongly believed that race and culture were unrelated, leading them to take on colorblind perspectives. "Why does it have to be race?" asked

Christine. “I understand culture, but I don’t understand the race part.” Victor agreed, “There’s nothing [in relation to culture] that’s race. The only thing I *don’t* ever tell my students is to look at themselves as Hispanic.” Julia stated, “It irks me a little bit when I see what percent African-American we have [within our student demographics], what percent Caucasian-- I don't even want to see that. Let's not distinguish. Let's treat them all the same.” As Milner (2012b) asserted, colorblind perspectives can make it almost impossible for educators to acknowledge systemic discriminatory policies and practices present in the education system, such as the overrepresentation of African American males receiving discipline referrals contributing to time out of class and less learning opportunities. Yet, participants believed that colorblindness was something to aspire to.

These five participants’ colorblindness was not apparent until the final PD week when we analyzed a video lesson in which an African American teacher provided instruction for his second-grade class in which 100% of the students were also African American. The lesson intentionally integrated issues of social justice that were important to the community, while also encouraging the children to go to college so they could one day return to their community and help to improve it. Christine and Victor found it disturbing to hear such young children speak about the crime in their neighborhoods and retell historical accounts of Black students not being allowed to attend White schools. “Does anybody else see maybe a small problem with this being a black school talking about white schools?” Christine asked. “Like they’re seeing white people as mean.” “Yes, that is exactly what I was thinking about,” Victor responded. Christine continued, “Why does it have to be about race? I understand culture, but I don’t understand the race

part, I guess." Though they did not specifically state that they were color blind, Karen and Dorothy both nodded in agreement.

When a racial mismatch exists between teachers and their students, teachers often understand social realities from their own frame of reference. This aligns with previous research findings from Ullucci and Battey (2011) – "Because my race doesn't impact my life, race doesn't impact others either" (p. 2012). After this conversation occurred, I went back to analyze data collected previously to see if there was evidence of participants' colorblindness that I had missed, simply because I was not looking for it. For example, Julia wrote the following while responding to her Pre-PD Questionnaire: "Actually, none of the sociocultural identities listed above [race, language, class, culture, gender] inform my decisions about creating and delivering math lessons." As I wrote in my field notes, *Julia and Christine show signs of color blindness that I didn't see before. I am going to add a "color blindness" code so that I will continue to pay attention to it.*

Meritocracy and the value of hard work. Participants often attributed their own success to hard work and persistence while attributing the failures of their students to specific deficiencies, such as laziness, lack of confidence, or fear of making mistakes. With the exception of Elena and Sofia, all participants attributed their successes to their hard work and persistence. "I made it my own goal I am going to work hard, I am going to push through. It was my goal to make the dean's list every semester and graduate," Dorothy described during a PD discussion, as she was explaining her path towards becoming a teacher. Evelyn and Ada believed that successful people had to be "go-getters" and "independent." Karen described hard work as a value instilled at home – "My parents always told me that as long as I was working my hardest, they were happy."

Five participants, Victor, Ada, Karen, Dorothy, and Evelyn, agreed that their parents set a positive example of hard work and persistence for them to follow. Contrapositive to this belief is that people who do not experience success did not work hard enough, discounting the effects of structural inequities that keep underserved student populations underserved.

Descriptions of traits possessed by their students who they perceived as unsuccessful thus far were the opposite of hard-working and independent, described by seven participants as lazy or giving up to easily, including this statement from Victor– "If they're not told to do something, or to come up with something, or think of something, they don't." Other times, participants described their students as lacking perseverance and refusing to work hard: "If there's just one part [of an assignment that a student does not understand], that's it. She shuts down. If she sees a bad grade, her day is done, she's not going to learn." These statements reflect Milner's (2012b) myth of meritocracy, believing that if a person works hard enough, they can and will be successful.

Interpretations of family/community support and values. All participants, with the exception of Christine, Evelyn, and Elena, described their parents as regularly involved in their education and/or holding high expectations for their children's schoolwork. They were open to discussing the dynamics of family expectations and involvement in their education at length, noting differences between their own experiences with family involvement and how they perceived the actions of their students' families. Ada, Karen, and Dorothy all described multiple ways that their own parents supported their education while holding high expectations, such as taking them to school early or picking them up late so they could attend tutoring, checking their

homework, paying for and driving them to commercial tutoring centers, and giving them "pep talks" when they would stress over schoolwork. They felt unconditional support and assistance from their parents, as Karen described, "I didn't have to be perfect, but if I worked my hardest, they were satisfied."

These three participants also expressed the belief that many of their students' parents do not value their children's education. Sofia recalled a conversation she had with a parent earlier in the school year – "A parent told us this year that neither of them [mom or dad] finished high school and they are doing just fine. Their son didn't put forth effort at all in class because it has already been engrained him that he will simply follow dad's footsteps," interpreting these statements to mean that the child's parents simply did not care about their son finishing school. "When I say parents do not value education, I'm thinking about parents whom I've seen or tried talking to," said Dorothy. "These parents do not send any important papers back, or you try calling and they don't answer, they give you attitude or you hear it in their voice that they don't care and that I'm just taking up their time."

Four participants, Victor, Sofia, Evelyn, and Julia, stated that their parents held high expectations, yet described their actions as uninvolved because they did not necessarily need their help with schoolwork. "Math was something I could easily figure out how to do," Evelyn explained. "I never needed help with it." Though their experiences were different from those whose parents were highly involved in their schooling, they agreed that their students' parents do not see education as a priority. Julia voiced, "I do think that the parent's view on academics, or school, or math in particular is

part of their culture." Victor also held particularly strong opinions regarding parent involvement amongst students from low-income households –

> I think a parent doesn't value education as a result of a lack of vision of the long-term future. I think parents are used to the idea of the family economy to be week-to-week or day-to-day…Education is a long-term investment, and so they prefer to have the kids working at home. Because of that, parents have a lack of interest in creating a healthy environment for learning, buying tools for learning, giving support to teachers and finally not passing the idea to children that schooling will help their future socioeconomic development.

All four felt that parents' actions implied that they do not hold high expectations for student achievement.

The statements used by all seven participants align with findings from Foote et al. (2013) in which preservice teachers use their own experiences of parental support as the frame of reference when making sense of the actions of their students' parents, often determining their actions as uncaring. Participants believed that academic achievement was aligned to family support, as Sofia explained – "Generally speaking, successful students are those who have parents behind them encouraging and reminding them of the importance [of school]." This belief that their students' families do not care about education, combined with the belief that family involvement is necessary for academic success also aligned with research by Foote et al. (2013), as this deficit belief about student backgrounds kept teachers from questioning their own instruction and the extent to which their teaching was effective or appropriate for diverse student populations.

Summary. Participants' perceptions of vulnerable students and their families, particularly in comparison to their own experiences, reflect Gorski's (2016b) depiction of deficit ideology – "believing that poverty itself is a symptom of ethical, dispositional, and even spiritual deficiencies in the individuals and communities experiencing poverty" (p. 380). Instead of acknowledging the inequities that act as barriers to equity for these students, participants interpreted their actions as uncaring and unmotivated to succeed. As research by Wilhelm et al. (2017) described, when teachers blame students' difficulties in learning on factors outside of school, such as their families or community, the nature of the opportunities to learn they afford to these students tend to include less cognitive demand and critical reasoning than the opportunities afforded to their classmates.

Influence of mathematical backgrounds and experiences. Each week, participants were asked to write autobiographical reflections in response to a prompt about their previous mathematical learning experiences. According to Aguirre et al. (2013), "Teachers' autobiographies offer stories of supports and challenges that clearly have had a powerful impact on their own math learner identities—and, not surprisingly, a significant impact on their vision of what they want for their own students" (p. 38). The first 10-15 minutes of the following meeting was then spent sharing and making sense of their experiences, connecting them to their current self-concepts and practices. Data collected from math autobiographies, transcripts from PD sessions, and transcripts from semi structured interviews, summarized in Table 10, revealed two areas influenced by participants' mathematical backgrounds and experiences: (a) their perceptions of

mathematics as an inherent ability or learned skill, and (b) what it means to "know" math in terms of rigor and cognitive demand.

Table 10

Mathematical Categories and Codes Identified by Thematic Analysis of Qualitative Data

Categories	Codes	Sources of Qualitative Data	# Participants	Code Frequency
Nature of Learning Mathematics (27)	Fixed ability- Have always struggled *(Background/Experience)*	PD Weeks 2 and 3; Math Autobiographies; Interviews; Field Notes; Memos	3	9
	Fixed ability- Always easy *(Background/Experience)*	PD Weeks 2 and 3; Math Autobiographies; Interviews	3	7
	Growth- Enjoyed the challenge *(Background/Experience)*	PD Weeks 2 and 5; Memos	2	4
	Growth- Memorable turning point *(Background/Experience)*	PD Weeks 2 and 4	4	7
What Counts as Knowing Math (26)	Memorization (formulas, recall of math facts) *(Beliefs/Attitudes)*	Interviews	1	3
	Procedures without connections (follow given steps to arrive at an answer) *(Beliefs/Attitudes)*	Pre-PD Questionnaire; Interviews; Memos	5	6
	Procedures with connections (use multiple representations, other math concepts) *(Beliefs/Attitudes)*	Pre-PD Questionnaire; PD Weeks 3, 4, and 5; Interviews	8	11
	Doing mathematics (complex, non-prescriptive thinking) *(Beliefs/Attitudes)*	Pre-PD Questionnaire; PD Weeks 2 and 4; Memos	5	6

Mathematics as inherent ability or learned skill. Participants each recounted at least one event within their mathematical learning history that had a significant impacted his or her self-concept as either "good" or "bad" at math. Victor, Sofia, Julia, and Evelyn described almost exclusively positive experiences with mathematics. Several other similarities were found between their stories, including their enrollment in advanced math

courses in both high school and college, the belief that their families were supportive and valued their education, an emphasis on independence, and the belief that they did not need outside assistance to succeed. With the exception of Victor, their statements implied that their mathematical abilities were inherently natural, using phrases such as "I'm naturally a math brain," "I was a wiz at math," and "I was always confident that I was one of the best in my class." This perspective of math as an inherent ability tended to parallel their teaching philosophies and beliefs about their students. As Julia believed, "Not everyone is college material."

Dorothy and Karen spoke almost exclusively of negative mathematical experiences, despite the high levels of support they received from their parents and teachers. Dorothy described her lack of confidence as she continued to experience failure – "I struggled a lot. My parents were always involved, always talked to my teachers, I had tutors, my teachers helped tutor me so I always had lots of help. I just wasn't strong." Karen also referenced how much her parents helped her with math outside of school, yet she continued to struggle from elementary school, where she repeated a grade level, through college.

Reflections written within memos foreshadow the similarities between their personal experiences and their approach to mathematics instruction— *I wonder if there is any connection between their fixed view of math learners and their own math identity...* Similar to the group of participants with exclusively positive math-related experiences, they frequently made deficit-oriented statements about students they perceived to be unmotivated to work hard. "I [thought about why students do not want to think in my class], and I think that maybe because at home, they're not pushed to think fast. Mom and

Dad aren't there to push them," Karen explained. As McCulloch et al. (2013) found, "Teachers have primarily negative early experiences, and accepted those early negative experiences learning math as a foreshadowing of lifelong mathematics weakness" (p. 383).

Ada, Christine, and Elena described math-related experiences in which they struggled up to a certain point, but were able to overcome a challenge, resulting in a positive self-concept as a math learner. The turning point for all three occurred well into adulthood, after starting their careers in education. Each one experienced a pedagogical approach using models for mathematics teaching that they were never given the opportunity to experience as students in the classroom. Ada reflected on the struggles she experienced before taking courses in math education while in college –

> I don't ever remember doing a lot of like hands-on things [as a child]. All I really remember is doing just things out of the textbook. As I got into junior high and high school, it got harder for me…I always had a tutor. Then, my first year in college, I was in a remedial college math course before I got to take the actual math class [for credit]. As I got older, it was still hard for me to just grasp things, but it was never hands-on, and that's more how I learn.

She did not grow to love math until she was a self-contained teacher and had the opportunity to experience different mathematical models beyond standard algorithms completed with pencil and paper. "That's when I grew to love math the most," Ada explained.

Elena, "I never understood [the mathematics behind the procedures]. Like…I knew that place value of one and ten and how to take away [to regroup when

subtracting], but I did not *understand* it until, literally, teaching it in second grade." She and Christine both felt that they did not receive support from their parents. As Christine described, "I didn't have the warm fuzzy thing, I didn't have that at all. My mom was no help whatsoever, my dad was not very nice, and according to him, she wasn't smart enough to do math anyway." Similarly, Elena could not recall her parents helping her with homework or being involved in her academics, referencing the gender inequities she experienced growing up in Venezuela. Both used these experiences as examples of what they themselves should *not* do.

Some of these findings contradict existing research by McCulloch et al. (2013) in which teachers described as "consistently frustrated" learners described the people who negatively impacted their experiences with learning mathematics in detail rather than those who were supportive. Additionally, none of the participants in this study who experienced a positive turning point within their math learning history described people who provided support to help them become successful, while those studied by McCulloch et al. (2013) wrote about multiple sources of support – "Positive changes were always related to a particular teacher who made them feel comfortable, cared about, and believed in" (p. 388). One possible explanation for these differences could be the focus of the autobiographical writing prompts specific to each study – the prompt presented by McCulloch et al. (2013) asked for specific examples of places, people, and activities within participants' memories of learning mathematics while prompts in the present study were more general, such as *What was learning math like for you as a child in school?*

What it means to "know" math. Prior to PD participation, teachers were asked, "What does it mean to 'know' math? How can you tell when your students 'know' the

math you are teaching them?" Beliefs about what constitutes mathematical understanding generally fell under one of four categories ranging in cognitive demand and level of application, though some statements included references to more than one. From lowest to highest cognitive demand, these categories included (a) memorization, (b) procedural understanding, without connections to other mathematical or problem-based concepts, (c) procedural understanding, able to make mathematical connections to analyze and applying reasoning to a given problem (d) doing mathematics, able to communicate understanding across contexts and apply to meaningful, real-world problems. While no participants indicated that memorization, the lowest level of cognitive demand, was the most important area of knowledge, it is included within the four categories of cognitive demand because it was a topic of conversation for some participants.

Evelyn, Ada and Dorothy indicated within their pre-questionnaire responses indicated that they most valued procedural mathematics without connections, or the ability to follow a prescribed algorithmic process to arrive at a correct answer. As Evelyn described, "I feel that to "know" math means that you understand the concepts and how to arrive at an answer by understanding the method to get there. I can tell my students know the math by observing them arrive to an answer." Victor, Christine, Karen, and Julia indicated that in order to "know" math, students must be able to reason and make connections between mathematical ideas and representations to solve a given problem. As Julia explained, "Not only should the students understand *how* to solve math problems, but *why* they are solved that way." This notion was taken one step further by Karen to include the connections and understandings that build throughout a child's education –

> [Students need] to understand why each step needs to happen, as well as to understand how math builds through the years. For example, with place value they have started in the first grade with expanded form and continue into fourth grade, but each year, a new set of values has been added. Then in fourth grade we take it one step further with expanded notation.

Unfortunately, students who are exposed to mathematical tasks that are lacking in cognitive demand are missing out on valuable opportunities to participate and learn mathematics at levels comparable to their peers (Wilhelm, Munter, & Jackson, 2017). Only two participants, Sofia and Elena, demonstrated a more complex notion of mathematical understanding, indicating that to "know" mathematics, students need to reach a conceptual understanding with the ability to effectively apply non-prescriptive mathematical ideas in a problem-solving context. "When they can explain [the mathematics] using their own examples, or daily life situations to explain a math concept…when they can explain, it means they understand it," Sofia wrote.

Summary. Before they are able to engage in culturally responsive teaching practices, teachers must first acknowledge and understand the impact of their own sociocultural perspective on how their approach to instruction (Hammond, 2015). This is especially important within mathematics classrooms, as the subject matter is usually perceived as context-free. Koestler (2012) explains –

> No content area, including mathematics, is neutral, and therefore teaching is not neutral. The topics teachers include (or do not include), the activities they ask students to do, and the forms of participation they demand—these all send messages to students about what is important, valid, and valued in mathematics

> and in school. This lack of neutrality is also true with respect to what teachers value in mathematics: they can either emphasize memorization or emphasize learning with understanding through guided investigation. (p. 84)

Three themes in beliefs and attitudes towards education were found to be influenced by participants' sociocultural backgrounds and experiences were identified: (a) the roles of, and connections between, race and culture in education, (b) meritocracy and the value of hard work, and (c) interpretations of family and community support and involvement. Additionally, two themes in beliefs specifically about mathematics teaching and learning were found to be influenced by participants' mathematical backgrounds and experiences: (a) their perceptions of mathematics as an inherent ability or learned skill, and (b) what it means to "know" math in terms of rigor and cognitive demand.

The activities teachers choose to *not* include (Koestler, 2012), as well as topics they choose *not* to discuss (Glesne, 2015) can be just as telling as the activities and topics discussed openly. One such topic within this research was race in the mathematics classroom. Participants were almost universally colorblind, denying any inequality within their classrooms. Though participants were well-meaning in proclaiming colorblindness, as Battey (2013) asserted, an unwillingness to question institutional racism, paired with disparities in academic achievement, allows us to blame perceived deficits within students, their families, and their culture. This was apparent through participants' deficit-oriented language, such as stating that families are uncaring and do not value education, interpreting parents' dislike for math is "part of their culture," and labeling some students as the "low kids." As Ullucci and Battey (2011) explain, the goal is not to treat race and

culture as if they are inconsequential – "Our objective is to eradicate racism, not eliminate race" (p. 1198).

The pedagogical side of the CRME Framework includes three dimensions based on Rubel and Chu's (2012) Culturally Relevant Mathematics Pedagogy – *Teaching math for understanding, centering instruction on students' experiences, and developing students' critical consciousness with, and about, mathematics.* Teachers' beliefs and dispositions concerning their students' potential for success, as well as their beliefs concerning math itself, must reflect these pedagogical dispositions in order to enact the CRME Framework. To teach math for understanding, teachers must help students make connections between facts, procedures and concepts (2012). If the tasks teachers provide for their students are only to the depth of procedures without connections, they will not be challenged to the same rigorous level as their peers, lacking exposure to deeper levels of understanding and rich mathematical conversations. If teachers see students' backgrounds, families, and communities as deficits, it is unlikely that they would try to pull from their cultural- or community-based funds of knowledge to address the second dimension, centering instruction on students' experiences. Finally, the third pedagogical dimension of the CRME Framework based on Rubel and Chu's (2012) Culturally Relevant Mathematics Pedagogy is *Developing students' critical consciousness with, and about, mathematics*. If teachers are unable to acknowledge the structural inequities that their students face based on their race, class, and/or culture, especially within the hierarchical tracking of mathematics education courses, they will be unable to fully enact the CRME Framework to meet the needs of their most vulnerable students.

These beliefs, attitudes, and understandings based on participants' prior experiences provide a starting point for each as they engage in professional learning activities facilitated throughout the PD series, leading into the second research question: How does PD for CRME influence participants' understanding and approach to equitable and accessible math education?

Data Presentation and Analysis for Research Question 2

The second research question was asked to understand in what ways, if any, were participants' understandings and approaches to equity and access in math education influenced by a PD series to educate them on cultural responsiveness, resource-oriented ideologies, and equity and access in math education. The purpose of the PD was to inform participants' vision of math education to better understand and serve diverse student populations. According to Gresalfi and Cobb (2011), "Coming to identify with a new vision of teaching is an important first step towards the more ambitious changes required if teachers are going to alter and improve their classroom practices" (p. 300).

Data obtained from participants' responses to open-ended questions before and after PD participation were analyzed and coded to identify any changes in how participants wrote about equity and access from a sociocultural and mathematical standpoint. In addition, math autobiographies, PD video transcripts, and interview transcripts were analyzed to identify potential supporting evidence of change, as well as to document any specific turning points or "aha" moments for individual participants. Four themes emerged as a result: (a) shifts between deficit- and resource-oriented language used to describe students and their backgrounds, (b) shifts in the cognitive

demand required to "know" mathematics, (c) a new emphasis on mathematical discourse and participation, and (d) new evidence of critical reflection and self-awareness.

Use of deficit- or resource-oriented language to describe students. One goal of the PD series was to support teachers in reassessing their beliefs about students and their capabilities for learning mathematics by focusing on the knowledge that students bring into the classroom instead of what they perceive students are lacking. Table 11 provides examples of deficit-oriented language and resource-oriented language used by participants. All participants utilized deficit-oriented language prior to PD participation.

Table 11

Deficit- vs. Resource-Oriented Language

Deficit-Oriented Language	Resource-Oriented Language
"Hopefully they will better than what their parents are doing."	"Knowing their family history and what their parents do contributes to examples I can use."
"They lack culture and community."	"I have to ask myself, 'Is this relevant to my students?'"
"Students don't have a lot of background knowledge."	"It takes learning your students to get through to your students. This job is way more than just teaching math."

Deficit-oriented language most often referred to students lacking the background knowledge or experiences needed to be successful, believing that the community does not prioritize education and holds low expectations for student performance, and interpreting parents' level of involvement with school as a lack of caring. deficit thinking can also lead educators to misinterpret actions taken by students' parents as uncaring and uninvolved, believing that they do not value their child's education. As Sofia stated, "There are parents that never check [homework or notes from the school]. I mean, I get

busy and don't always check everything, but never ever checking it and having no clue or concern at all about what's going on with your child and school is not ok." I asked her, "So, it's not that a parent has ever said to you, 'School is not important to me.' You interpret this message from their actions?" "Correct," she confirmed. "From their actions, or lack thereof. Generally speaking, successful students are those who have parents behind them, encouraging and aiding and reminding of the importance."

Memos recorded after the first round of coding align with these sentiments: *Family/community backgrounds and previous math experiences are blamed for students' "inability" to learn…They use it as a reason to hold low expectations for marginalized student groups. Going forward, I will make purposeful attempts to encourage language that values the diverse backgrounds and perspectives of their students.* Consistent with evidence from Gorski (2016b), participants perceived parents' lack of in-school involvement as evidence that "people experiencing poverty are the problem; their attitudes, behaviours, cultures and mindsets block their potential for success" (p. 381).

With the exception of Julia, all participants also utilized some resource-oriented language prior to PD participation. Resource-oriented language, on the other hand, values the knowledge that students *do* bring with them – "In other words, the 'problem' does not rest with the individual student or the community they come from, but with the opportunities that have (or have not) been provided to students" (Wilhelm et al., 2017, p. 348). Statements that utilized resource-oriented language included the use of students' backgrounds and experiences as essential funds of knowledge to draw from when teaching and learning mathematics, the positioning of students as valuable sources of

expertise, as well as the use of positive relationships with students and teachers to establish trust and respect.

After participating in five weeks of PD activities to educate participants on the CRME Framework, the group demonstrated a positive shift towards resource-oriented language, as post-questionnaire responses revealed a decrease from 16 to 7 deficit-oriented responses and an increase from 11 to 20 resource-oriented responses, as illustrated by Figure 3. Additionally, the number of participants utilizing deficit-oriented language after PD participation decreased from all nine participants to five participants. All nine participants utilized resource-oriented language after PD participation, as opposed to eight before the PD. For example, participants were asked, "In what ways, if at all, do/might the sociocultural identities of the students you teach inform your decisions about creating and teaching math lessons?"

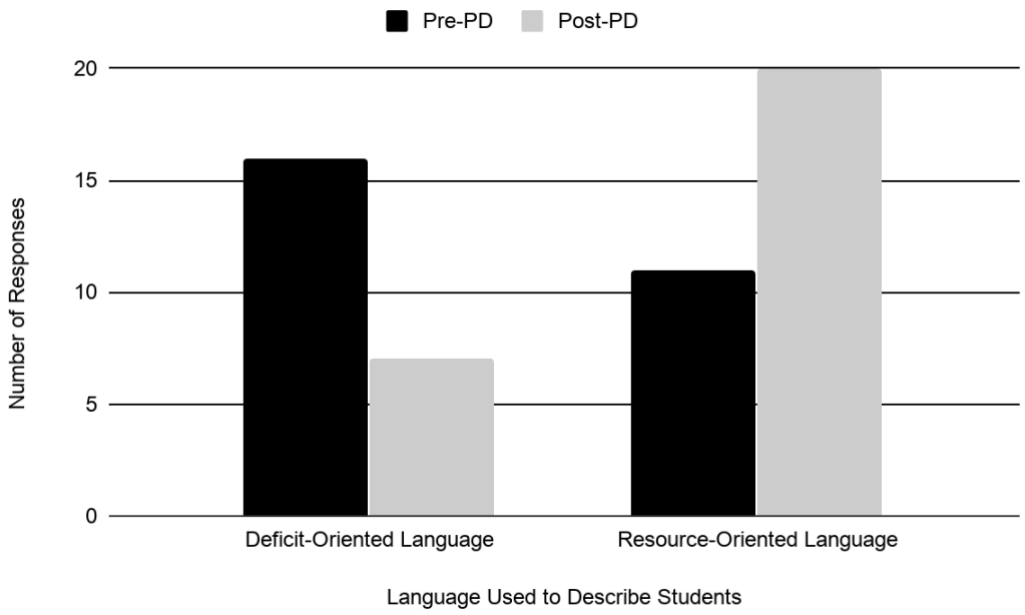

Figure 3. Participant use of deficit- and resource-oriented language.

Before learning about CRME, Elena's response was focused on her students' lack of experience handling money because of their socioeconomic status, believing they were

unable to relate to examples about money – "The examples I use have changed because of their socioeconomical level and background… These students do not tend to manipulate money like students from higher socioeconomic levels." However, after PD participation, she responded,

> I think that the examples we may use or books, tests, etc. can affect their understanding as they may not relate to what or how/why it is applied. Our own background can limit us in not being able to relate to their daily life. Besides, when we relate math to things they see, know and understand, and we explain the math behind that, their interest sparks and their "why" is clearer.

This response shifted from one that blamed the students' background to the teacher taking ownership of her students' opportunities to learn. These findings align with Gresalfi and Cobb's (2011) research in which new professional learning experiences helped participants to move beyond categorizing students dichotomously as either capable or incapable and talk about why students were misunderstanding new content.

All participants, with the exception of Ada, demonstrated a positive shift towards using more resource-oriented language and less deficit-oriented language. Interestingly, her classroom observation data was also the only class observed to not reflect the use of student background knowledge as a resource within her lesson, listed as a non-example – *Learning experiences are derived almost exclusively from published textbooks and other materials that do not relate to the classroom community or the larger community being served.* One potential explanation for this outcome is the short five-week timespan of the PD. While some participants began the PD more open to ideas concerning cultural responsiveness, Ada was the most uncomfortable, as reflected in a memo from the first

week: *Ada seem nervous, uncomfortable, and not completely open-minded about it* – and a statement she made before completing the pre-PD questionnaire – "This makes me feel uncomfortable," she confessed while completing her open-ended questionnaire prior to PD participation. "I don't know how to answer this. Can I skip it?"

Though she did not ask to skip any questions on her post-PD questionnaire, her responses did not extend any further than referencing general best practices, such as ensuring that she provides her students with hands-on experiences and small group instruction when needed. This could be attributed to the fact that the PD only lasted five weeks, not allowing her enough time to address any deeply implicit beliefs about her students. Battey and Franke (2015) also shared this concern, as they opted for a PD approach in which they chose not to address deficit perspectives early on, as teachers would become defensive or shamed into silence, and less likely to remain open to change.

Conversely, other participants, like Dorothy, demonstrated noticeable turning points in their assumptions about their students within the timespan of the PD. Prior to PD participation, Dorothy believed that getting to know students' families and communities was important because involved parents "seem to want to help their children achieve more," implying that parents who are unable to be actively involved in their child's schooling did not want their children to achieve. After PD participation, her response to the same question changed, as she now believed that families and communities was important because it helps her make connections to her students' experiences as valuable resources for learning "in order to make an impact on their learning." Dorothy later attributed this shift to a specific learning activity that impacted her perspective during the fourth PD week. As a group, we analyzed a video lesson from

the Teaching Channel (2018) using the Culturally Responsive Lesson Analysis Tool (TEACH MATH, 2012) as a concrete example of a culturally responsive math lesson. In the video clip, a teacher working in a school in Morocco taught a math lesson through by utilizing community resources to produce and sell olive oil – students tended to the olive trees, made estimations of the number of olives needed compared to how many they believed they would produce, and taking measurements. Students even observed a camel pulling a large stone around a circular pit to press the olives into oil, calculating the distance travelled by the camel around the diameter of the pit before eventually taking their olive oil to the community market to sell.

This particular experience helped Dorothy to understand how community resources can be used to help students make connections between mathematics and their lived experiences, resulting in a deeper understanding of the math involved. "It shed a different light for me, like, made me look at things differently," she said. "It made me think about what I can do to try to come from [my students'] view, and try to incorporate that into my learning, into my classroom." This confirms findings made by Aguirre and del Rosario Zavala (2013), who used the CRMT Lesson Analysis Tool to make cultural responsiveness explicit while engaging teachers in engaging and thoughtful discussion.

Shift in cognitive demand required to "know" mathematics. Participants' definitions of what counts as mathematical understanding varied in terms of cognitive demand and level of application. A teacher's preference for tasks that require a low cognitive demand can greatly affect his or her students' opportunities to learn. Grant, Crompton, and Ford (2015) explain, "High-level tasks that require students to engage mathematically, to seek connections to other mathematical ideas, and to prove their

approaches, require teachers to facilitate learning differently than low-demand tasks that only require students to recall memorized facts that teachers, in turn, validate" (p. 90). Once it once apparent that there were categorical differences between participants' beliefs about what it means to "know" mathematics, The Mathematical Tasks Framework (Stein, Smith, Henningsen, & Silver, 2000), a framework used to assess the cognitive demand of mathematical tasks, was chosen to organize and make sense of these differences.

From lowest to highest level of cognitive demand, participant responses were assigned to one of the following categories as outlined by The Mathematical Tasks Framework (Stein et al., 2000): (a) *memorization,* the reproduction of previously learned facts, formulas, or definitions, (b) *procedures without connections*, algorithmic processes with no conceptual connections and requiring no explanations (c) *procedures with connections,* utilizing multiple representations and pathways to build conceptual understanding, and (d) *doing mathematics*, complex, non-prescriptive thinking that requires students to access relevant experiences and knowledge to make sense of mathematical relationships and concepts. Examples of participant statements aligned with each category are provided in Table 12.

Table 12

What it Means to "Know" Mathematics by Cognitive Demand

Memorization	Procedures without Connections	Procedures with Connections	Doing Mathematics
"Memorizing makes stronger math students."	"I can observe students arrive at an answer."	"Able to apply math to a variety of problems."	"Think critically about problems and apply math in a social context."

At times, participants expressed beliefs about mathematical learning that applied across multiple categories. In these instances, the statement was placed at the highest identified level of cognitive demand. Figure 4 provides a comparison of participant statements before and after PD participation related to their beliefs concerning what it means to "know" mathematics. Dorothy, Ada, and Evelyn believed that mathematical understanding was accomplished by following a procedure and knowing "how to arrive at an answer," as Evelyn stated. However, all three participants demonstrated a preference for procedures *with* connections after PD participation, wanting students to explain their reasoning and justify their solutions using a "higher order thinking process."

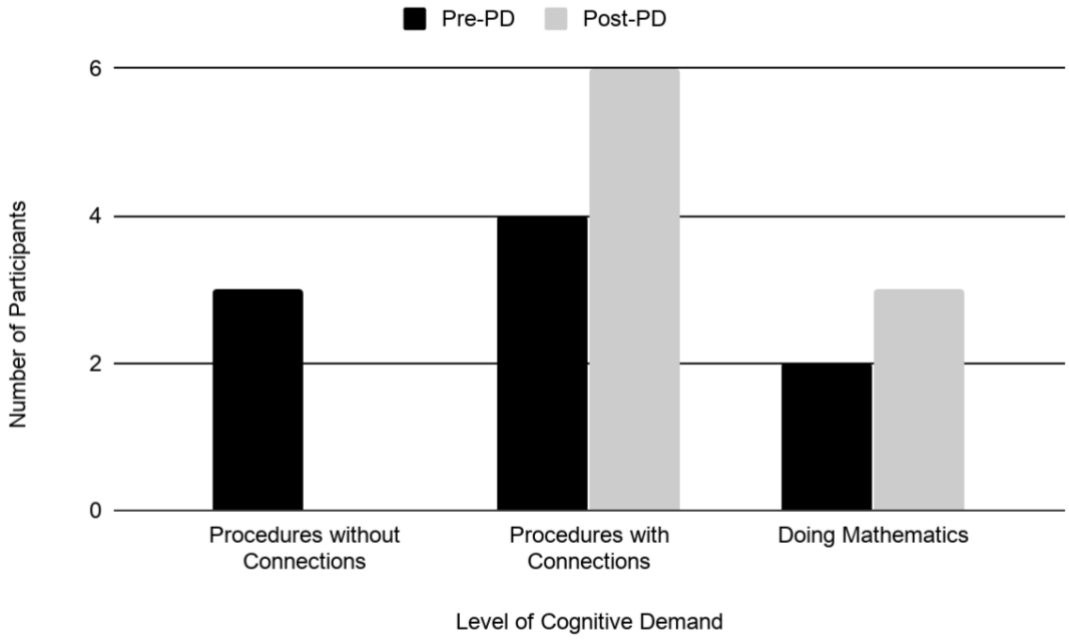

Figure 4. Participant emphasis on cognitive demand required to "know" mathematics.

These findings were later corroborated by classroom observations within all three classrooms. Ada and Evelyn were observed developing conceptual understanding of division with remainders while making connections between multiple representations, encouraging students to create drawings of problem situations, use manipulatives to create equal groups in various ways, and work with their classmates to understand what it

means if a number cannot be divided equally. Dorothy's students were also studying division, but she increased cognitive demand through class discussion, requiring students to justify and explain their reasoning.

Victor, Karen, Christine, and Julia began the study believing that understanding procedures with connections to other representations and concepts is what constitutes knowing mathematics. As Julia described, "Not only should the students understand *how* to solve math problems, but *why* they are solved that way. Included in this more in-depth approach is an excellent understanding of the vocabulary of mathematics." While Karen, Christine, and Julia maintained an emphasis of what it means to know mathematics at this level, a change in questionnaire responses from Victor revealed a new emphasis on the critical application of mathematics, representing the highest cognitive demand. Victor demonstrated a noticeable turning point during the second PD session while discussion Bob Moses' initiative, The Algebra Project, and its focus on math literacy as vital to the future success of marginalized students as he explained the initiative – "Instead of learning standard algorithm and *then* applying it to real world problems, the teachers show [students] the real-world problem first, then they figure out how math is going to help them to solve it. They're proving the need for math to the students before they even teach it." He was particularly interested in how The Algebra Project approached new mathematical vocabulary by using their own relatable language first to build deeper understanding, then adding the formal math terms afterwards. Victor continued reflecting on this idea and how it related to his own experiences– "I was thinking about how to apply that to my class…even if my students don't perform mathematically at the expected

level, maybe they have some other skills they can use to approach situations, right? I mean, they have other knowledge that they could use."

Victor's questionnaire responses after PD participation confirmed this change in focus. He wrote, "[Students] first need to be able to relate the use of mathematics to their lives, and then the processes created to solve problems…and lastly, the pure mathematics. In this sense, their social circumstances are intrinsically related to their understanding of math and the use of math." Though his classroom observation data mainly centered on procedures with connections through the use of multiple representations and student-to-student collaboration, such as partners using decimal grids to learn why two decimals multiply to make a smaller number, he did attempt to engage students in a relevant discussion of when they might need to multiply decimals in a real-world context.

Elena and Sofia, both bilingual teachers, began and ended the PD series with an emphasis on *doing mathematics*, the highest level of cognitive demand. As Sofia explained, "knowing" mathematics means that a student is able to "manipulate the information given to solve a problem, be it real-world or testing situation. It means that a student can assess a situation and comfortably know exactly what they need to do to get to the solution." According to Elena, a student "knows math when he or she "is able to explain in his/her own words."

Though the research timeline did not allow for a formal observation of Elena in her classroom, Sofia's instruction included multiple examples that required a high level of cognitive demand from her students, as students explained, reasoned, and justified

together the meaningful connections between old and new vocabulary as they worked to define the terms dividend, divisor, and quotient.

Increased emphasis on mathematical discourse and student participation. As participants began to emphasize teaching for conceptual understanding with cognitively demanding tasks while also decreasing their use of deficit-oriented language, references to student participation in the learning process began to emerge. As Aguirre (2012) explains, "When students have the opportunity to contribute to the classroom, answering and posing questions, justifying claims with evidence, voicing conjectures, and communicating their reasoning process, they build a more solid understanding." (p. 2). In this sense, decreased deficit thinking about students while also increasing the cognitive demand within the classroom may naturally include greater emphasis on student participation and discussion.

Participant statements referencing various aspects of student participation in the learning process through mathematical discourse fell into three categories: (a) student use of mathematical language and vocabulary, (b) student justification of solutions and/or explanation of reasoning, and (c) students as active participants in the co-creation of mathematical understanding. Though these categories are sequenced in order of complexity of discourse and participation, they are nonexclusive, as participants could reference them across multiple questionnaire responses. As they progress, each category assigns a slightly different role through which students participate. Table 13 provides an example of participant responses within each category.

Table 13

Mathematical Discourse and Student Participation

Mathematical Language & Vocabulary	Justify Solutions & Explain Reasoning	Co-creation of Understanding
"They can teach it back to me accurately using math vocabulary."	"Students justify answers, telling me *why* and *how* they got to the answer.	"We rely heavily on visuals, using their definitions [and mine] interchangeably."

Participant responses that included aspects of mathematical discourse or communication overall increased from seven statements before PD participation to 19 statements after PD participation. Not only did the overall number of discourse- and participation-related statements increase, but also the quality of opportunities for student participation at a rigorous level, as illustrated by Figure 5. Statements referencing student use of mathematical language and vocabulary increased from one participant, Julia, before the PD to three participant responses after the PD, including Julia, Evelyn, and Victor.

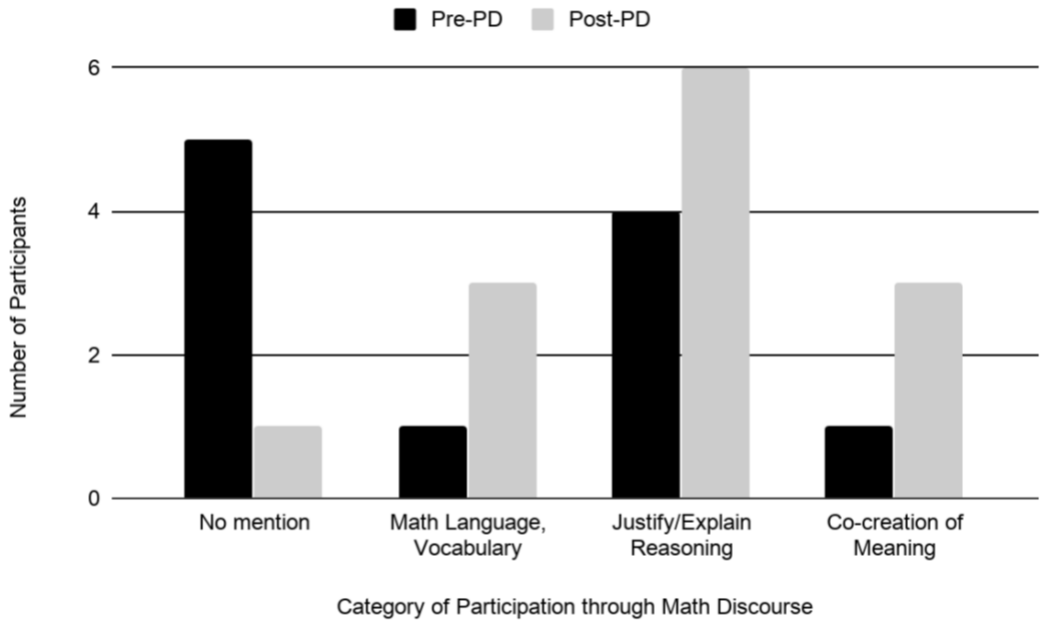

Figure 5. Participant emphasis on cognitive demand required to "know" mathematics.

Victor explained his shift in emphasis, stating, “Instead of only teaching kids how to calculate and solve problems, [I] teach how to understand the ideas and processes embedded in math language.” The use of math language and vocabulary was also evident in their classroom observations, as field notes documented “student-to-student math talk” in Evelyn’s classroom as they attempted to solve division word problems with concrete models in a collaborative group setting, as well as “collaborative learning and participation” in Victor’s class as students worked with partners to multiply decimals using decimal grids.

Statements that emphasized students justifying solutions and/or explaining their reasoning increased from four participant responses, including Elena, Julia, Sofia, and Karen, to six after PD participation, adding Dorothy and Ada to the group. As Karen wrote, “[I know students understand] when they can give me an explanation for their answer with correct reason and justification.” These findings were also verified by observational data recorded in Ava and Sofia’s classrooms indicating that both teachers used “critical thinking techniques such as requesting evidence, accepting multiple points of view, and respecting divergent ideas.” Additionally, while Karen’s classroom was still mostly dominated by teacher talk, she made purposeful attempts for students to answer questions, accepting multiple approaches and perspectives.

Finally, statements indicating that students play an active role in the co-creation of mathematical understanding increased from one statement before PD participation made by Sofia to three participants after the PD with the addition of Elena and Victor, emphasizing “the idea that mathematics can be understood with a social context.” Sofia’s lesson included the creating of an anchor chart with which she facilitated an engaging

discussion over what the class already knew about various math terms, asking "What do we already know?" in regards to operations vocabulary, such as addend, subtrahend, factor, and dividend.

Depth of reflection and self-assessment regarding equity. Though all participants engaged in reflection throughout the PD series, the depth of their self-assessment concerning their approach to equity in math education varied. The depth of reflection and self-assessment expressed by participants fell into one of three classifications – (a) surface-level reflection, describing equity without self-assessment or consideration for other perspectives, (b) mid-level reflection, considering outside perspectives and unique student needs with little to no self-assessment, (c) critical reflection, acknowledging the sociopolitical construction of perspectives and beliefs, and critically assessing their own perspectives and/or institutions. Table 14 provides examples of participants' reflective statements at each of these levels.

Table 14

Depth of Reflection and Self-Assessment

Level of Reflection	Reflective Statement
Surface-Level Reflection	"Every student should have access to all materials and instruction strategies available to the school."
Mid-Level Reflection	"I try to know as much information I can about my student's background to better target my instruction."
Critical Reflection	"I believe we have to be aware of our own identity and those of others and listen to what they have to say. We have to have conversations with the students and their families to understand what education means to them.

While some participants were able to communicate a deep understanding of equity and critique their own practice, others were only able to articulate vague, surface-level

descriptive reflection. Figure 6 illustrates the comparison of participants' reflections concerning equity in math education before and after PD participation.

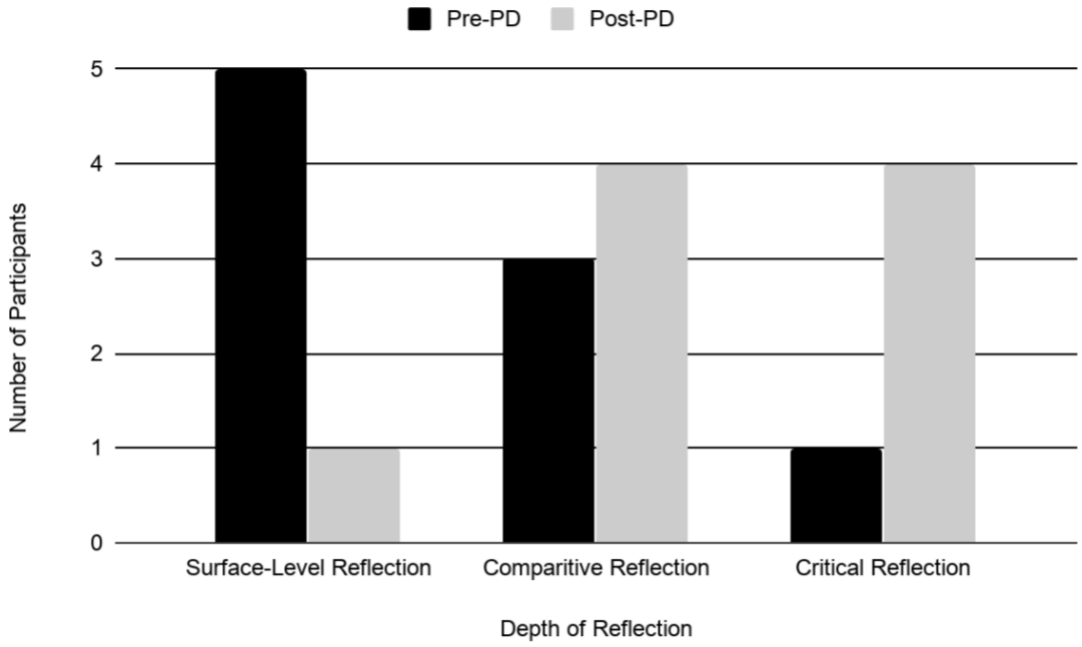

Figure 6. Participant depth of reflection and self-assessment.

Ada, Evelyn, Dorothy, Karen, and Julia engaged in surface-level reflection about equity within their pre-PD questionnaire responses. When asked what it meant to address issues of equity within their classrooms, their reflections tended to be general descriptions of equity that were not specific to their specific students or situations. For example, Dorothy responded, "When creating lessons, I always think about each class, what their needs are, and what I can do to better help them learn the material. I often think of activities based on what the class likes as a whole." Karen's response also referred to each of her classes as a whole, but utilized deficit language when describing their needs –

> I try to create lessons that can be modified to fit each class. For my GT class, I have more choices or open-ended options for them in stations that require higher-

> ordered thinking. For my low-level students, I use straight forward stations or assignments that provide explanations or directions to help with misconceptions and confusion.

After PD participation, Ada, Evelyn, Dorothy, and Julia engaged in mid-level reflections, acknowledging the importance of considering outside perspectives, particularly those of their students, when planning and delivering mathematics instruction – "When planning and delivering math instruction, it takes more than just looking at your grade-level math standards. It takes you knowing about your community that you work in and the community within your school." Though their questionnaire responses did not reflect a deeper level of reflection, several of them were able to reflect at a deeper level and self-assess at some point verbally through PD discussions.

During the third PD week, we read a vignette, *Building on Students' Strengths: The Case of Curry Green* (Aguirre et al., 2013), about two teachers who were discussing a particular student. The first teacher, who had the student in class the previous year, warned the second teacher that Curry Green was far behind in math – he did not know his multiplication facts, cannot focus because he just wants to draw all the time, and is a disruption to the rest of the class. She is sure that he will continue to get further behind his classmates because he does not have fact fluency, and she believes he cannot move on to more advanced problems until he memorizes his math facts. The second teacher disagrees with her perspective and plans to introduce multiplication using more visual representations, such as a rectangular array, and find ways to integrate Curry Green's love of drawing into her lesson the following week. Reflecting on her personal experiences in relation to her classroom, Elena started the discussion after the reading –

> We make decisions on the basis of what we believe, and I think that's very important. Thinking about my own experience, I put a lot of emphasis on teaching math for girls just because I believe, based on my own perspective and experience, that they are not challenged at home the same way boys are. And that affects what I do in the classroom: I make a lot of girls participate and be more active than the boys.

Elena's reflection on how her personal experiences address equity in her classroom made Evelyn think about how a teacher's approach to instruction could negatively impact a classroom –

> I feel like your experiences can have a positive or a negative effect [on your students], do you know what I mean? Like, Christine mentioned that she has a hard time teaching with pictorial models, because that is not how she was taught. She made the change, but if you have another teacher that was taught [just using algorithms], but maybe they are set in their ways, then it's harder for them to change, do you know what I mean? That's why I think your experiences can be a positive or a negative.

Dorothy also engaged in deeper levels of reflection throughout the PD than her post-PD questionnaire responses. Her students had recently completed a project in which they worked with their peers to create a math game that would help their classmates review a specific math concept learned throughout the year. This type of project was different from any other she had assigned, and she was concerned that she would lose control of the class by giving them so much freedom and decision-making power. She was pleasantly surprised when she realized how seriously her students took the project and

how creative all of their games were. This caused her to reflect deeply on her usual structured approach to mathematics instruction and how little input she allowed her students to have. "I didn't have to just sit there and help them, they ran with it," she recalled. "I've heard that the more imagination you have, the more intelligent you're supposed to be. Maybe we've taken that out [of our instruction], and they need that. They need that again."

Karen was the only participant to not engage in deeper level of reflection after PD participation, stating, "I feel you need to give every student, regardless of their skill level or home life, an equal opportunity to see as much growth in themselves as any other student in the class." This general detachment from confronting what it means to address equity issues within her classroom aligned with her traditional perspectives of mathematical teaching and learning as neutral and unaffected by context, as confirmed by her post-PD questionnaire in which she stated that she did not believe her sociocultural background or prior experiences affected her instructional decisions.

Victor, Christine, and Sofia engaged in mid-level reflection before PD participation when asked what it means to address issues of equity in math education. Their reflections indicated a need to create equitable learning opportunities by centering instruction on their students' experiences but lacked self-assessment and critique. As Victor explained, "I try to know as much information I can about my students' backgrounds to better target my instruction…I adapt written language, background stories for the problems, and the use of media/manipulatives according to what I think will work best for my students."

All three participants demonstrated deep, critical reflection after participating in the five-week PD series. Elena, who engaged in critical reflection prior to PD participation, maintained this reflective depth, resulting in a total of four participants able to critically reflect and self-assess their approach to equity in the mathematics classroom. They also engaged in critical reflection significantly more often throughout the PD series than other participants. Their reflections had several commonalities, including a deep level of self-knowledge, clarity and specificity in relation to cultural responsiveness, and an analysis of one's own worldview. For example, Elena provided the following critical reflection after PD participation –

> Gender expectations, prejudices and misconceptions affect us as teachers and students as well. For example, finding GT student in a bilingual classroom is harder because of limitations in the identification program, making us assume we don't have GT students, so we don't push or challenge for kids who may excel in math. So, I believe we have to be aware of our own identity, and of others, and listen to what they have to say. We have to have conversations with the students and their families to understand what education means to them, both math and school. When we plan, we have to be sensitive to our classrooms…what works in mine may not work in yours, and that is fine. Flexibility and adaptability are important to show respect.

She was also critically reflective throughout the PD series. During the fourth PD week, we watched a video clip of a Black teacher using culturally responsive teaching to empower his elementary students, 96% of whom were African-American, in an urban charter school. His students were able to recognize and speak to the problems they saw

within their own community, including violence and homelessness, as well as their desire to go to college so they could get a good job and help to make their community a better place for future generations. When the video ended, Elena was the first to respond – "I think it was naive of me not to… to think that... students that young are not personally aware that they're killing each other. That shocked me. It makes me wonder, what do my second graders know [that I think they are not aware of]?"

Summary. PD opportunities for cultural responsiveness rarely cross paths with mathematics education, resulting in missed opportunities for teachers to learn how to make important connections within their instruction (Hudley & Mallison, 2017). This research question required the analysis open-ended questionnaire responses collected before and after PD participation in order to identify any shifts in how participants understood or approached equity and access in math education, triangulated by classroom observations, participant interviews, and evidence of turning points within the PD series. Four themes emerged: (a) shifts between deficit- and resource-oriented language used to describe students and their backgrounds, (b) shifts in the cognitive demand required to "know" mathematics, (c) a new emphasis on mathematical discourse and participation, and (d) new evidence of critical reflection and self-awareness. Chapter 5 will discuss connections between these shifts and teachers' participation in the PD series, as well as implications of this research for instructional leaders and PD facilitators and recommend potential directions for future research on cultural responsiveness in mathematics education.

Chapter V

Discussion

Guided by the CRME Framework, this study investigated two research questions– (1) How do teachers' sociocultural and mathematical backgrounds and experiences influence their understanding and approach to equity and access in math education? and (2) How does PD for CRME influence participants' understanding and approach to equitable and accessible math education? This action research sought to bridge the gap between research and practice within a mid-sized, rural district by addressing two essential strands of education – *pedagogy*, the dispositions and beliefs teachers bring with them to into the classroom, and *teaching*, teachers' actual instructional practice. Chapter 4 presented an analysis of the data and subsequent findings pertaining to each research question. This chapter will summarize and discuss these findings, consider implications for professional development and the CRME Framework, for district and instructional leadership, and provide recommendations for future research before its conclusion.

Summary and Discussion of Findings

Before teachers can recognize and respond to sociocultural backgrounds different from their own, they must "internalize that their cultural lens – or the beliefs based on the compilation of their life experiences – is different than the lens of their students" (Goldenberg, 2014, p.11). Awareness of one's own beliefs and attitudes about teaching and learning, accompanied by prior experiences within mathematics education, is critical to understanding the perspectives of others and adopting a culturally responsive approach to teaching mathematics. This section will address findings related to participants' beliefs, attitudes, and experiences as they relate to each research question.

Research question 1. How do teachers' sociocultural and mathematical backgrounds and experiences influence their understanding and approach to equity and access in math education? Reflecting on one's own identity, values and beliefs, as well as how they may affect classroom instruction, is an important step towards recognizing and addressing the inequities of students' opportunities to learn (Nieto, 2017). Each participant began this study with a unique sociocultural and mathematical background that informed their assumptions and values in relation to math, education, and ability in different ways. Therefore, each individual's understanding of equity and access within the classroom was a product of his or her social and cultural frame of reference. Themes in participants' sociocultural backgrounds included (a) the roles of, and connections between, race and culture in education, (b) meritocracy and the value of hard work, and (c) interpretations of family and community support and involvement. Themes related to prior mathematical experiences included (a) their perceptions of mathematics as an inherent ability or learned skill, and (b) what it means to "know" math in terms of rigor and cognitive demand.

While participants openly discussed social class as an aspect of students' experiences, there was a level of discomfort when discussing the role of race/ethnicity within mathematics education. Several participants, perceiving colorblindness to be synonymous with not racist, drew a distinction between culture and race. "When I think of a student's culture, I think of their home and where they're coming from. That's what I think of. It doesn't matter if they are White, Black, Hispanic, Asian…that doesn't matter," one participant explained. Ullucci and Battey (2011) provide the following example of how colorblindness can lead to a misreading of social realities –

> All that I have earned has been through my hard work (merit). It is my own personal characteristics that have led me to my success (individualism). I live in a society in which my being White is inconsequential; I do not receive material benefits because of my skin color (Whiteness). The lack of students of color is just happenstance (color blindness). Because my race doesn't impact my life, race doesn't impact others either (color blindness). (p. 1202)

Students' perceptions are their realities, and when teachers claim to "not see color," they risk devaluing race as an important aspect of how racially diverse students understand their own identities (Milner, 2012a). In Goldenberg's view, educators of diverse student populations must accept that "students perceive the classroom, school, learning, and them (a White teacher) differently than how that teacher thinks the students should perceive these characteristics" (Goldenberg, 2014, p. 11). This finding confirms research conducted by Aguirre and del Rosario Zavala (2013) and Jackson and Jong (2017), noting discomfort from participants that acknowledging race meant crossing the line between cultural responsiveness to racial stereotyping.

Though their intentions were good, participants' deficit-oriented beliefs led them to hold low expectations for behavior and achievement from diverse student populations, particularly those from low-income backgrounds. Gorski (2016b) recommends asking a single question to determine if a school's leaders and initiatives are driven by a deficit or structural ideology: "Why, on average, do parents from families experiencing poverty not attend opportunities for family involvement at their children's school with the same frequency of their wealthier peers?" (p. 381). Participants often cited their hard work and persistence for their own successes – "Everyone is responsible for their own success" –

implying the belief that if a person will just work hard enough, they will succeed (Milner, 2012b). The contrapositive of this would mean that people who are *not* successful do *not* work hard, leading to deficit assumptions about students' capabilities. Confirming earlier work by Foote et al. (2013), this indicates that participants used their own experiences to frame their perceptions of what counts as family support and involvement, believing anything different is deficient.

The same participants perceived struggling students as less capable of achievement because, from their limited perspective, their parents did not appear to be involved or interested in their schooling. As prior research has confirmed, some parents are hesitant to participate in regular school activities or conferences because of prior negative or uncomfortable experiences, and the teacher often concludes that the parents must not value education as a result (Hawley & Nieto, 2010). Deficit beliefs concerning students living in poverty can be dangerous, influencing teachers' instructional choices and resulting in inequitable opportunities for marginalized student groups (Hammond, 2015).

A teacher's vision of high-quality math instruction can have a profound effect on students' opportunities to learn, as the cognitive demand of a chosen task likely reflects their goals for instruction (Wilhelm, 2014). As Darling-Hammond et al. (2015) suggest, in order to teach for understanding, teachers must engage students in learning that "enables critical thinking, flexible problems solving, and transfer of skills and use of knowledge in new situations" (p. 2). Participants differed in their views of what counted as "knowing" mathematics, ranging from procedural computations with low cognitive

demand to deep conceptual understanding through mathematical discourse and problem solving in context.

Herein lies the importance of understanding both teachers' sociocultural and mathematical beliefs and values – teachers who hold deficit views of students' abilities do not believe all children are capable of learning at high levels, leading them to hold low expectations for mathematical learning and lowering the cognitive demand of instructional tasks. The pedagogical side of the CRME framework is dependent upon teachers centering instruction on students' experiences (Rubel & Chu, 2012); therefore, a teacher who overemphasizes computation and algorithms is unable to fully embrace CRME, holding low expectations for student understanding. For these teachers, application of mathematics outside of the classroom context is not the goal of instruction, especially if they believe that they have "low" kids. Deficit-oriented beliefs about students and their abilities are "antithetical to knowing students in a culturally responsive way" (Parker et al., 2017, p. 388).

Research question 2. How does PD for CRME influence participants' understanding and approach to equitable and accessible math education? The language we use to describe our beliefs about teaching and learning is important, as the way we describe our problems can limit the solutions we are able to consider (Gorski, 2016a). The second research question was developed to understand the influence of teachers' participation in a PD series for CRME by analyzing changes in the language used in responses to a questionnaire before and after PD participation. Themes identified included: (a) shifts between deficit- and resource-oriented language used to describe students and their backgrounds, (b) shifts in the cognitive demand required to "know"

mathematics, (c) a new emphasis on mathematical discourse and participation, and (d) new evidence of critical reflection and self-awareness.

Deficit-oriented language is rooted in the belief that vulnerable students are less capable of reaching high levels of achievement than their advantaged peers because of their families, backgrounds, communities and/or inherent abilities (Grant et al., 2015). Prior to becoming culturally responsive, a teacher must engage in critical reflection in order to bring any deficit beliefs about students and their abilities to the surface and replace them with asset-oriented beliefs and high expectations (Gay, 2013). However, well-intentioned educators may unconsciously hold deficit-oriented biases that surface as pity, feeling sorry for their vulnerable students, holding low expectations, and presenting low-level instructional tasks, reducing students' opportunities to learn math at high levels (Milner, 2012a).

Teachers must come to terms that that their understanding of the world is limited to their own cultural frames of reference before attempting to address equity and access within math education (Goldenberg, 2014). Prior to PD participation, participants utilized more deficit-oriented language, blaming students' families, communities, and lack of motivation for differences in achievement, than resource-oriented language. But after participating in five weeks of PD for cultural responsiveness, participants demonstrated an increase in resource-oriented language and a decrease in deficit-oriented language.

The view of mathematics as free from context or bias has been normalized in mathematics education, understood to be a universal truth unaffected by social contexts (Parker et al., 2017). However, not all math classrooms offer equitably rigorous, cognitively-demanding math instruction that ensures all students can access new

understandings. Participants in this study differed in their beliefs about which aspects of mathematics are most important, expressing preferences for either procedural or conceptual understandings. From pre- to post-PD questionnaire responses, eight of nine participants demonstrated a shift towards a preference for more conceptual understanding.

While both procedural and conceptual understandings of math are important, the cognitive demands associated with latter provide greater opportunities for learning at higher levels, as students can engage with more rigorous mathematical ideas and make connections with other contexts (Wilhelm et al., 2017). As Grant et al. (2015), stated,

> The cognitive level of the task affords different types of teaching and learning opportunities. High-level tasks that require students to engage mathematically, to seek connections to other mathematical ideas, and to prove their approaches, require teachers to facilitate learning differently than low-demand tasks that only require students to recall memorized facts that teachers, in turn, validate. (p. 90)

As the mathematical application becomes more complex, so did the cognitive demand required to complete the task. This is important to consider when working with traditionally underserved students, as research has shown that historically underserved students do not often benefit from traditional approaches to remediation, such as low-level skill remediation, and need more equitable opportunities to learn at high levels (Grant et al., 2015).

Ensuring students have opportunities to participate in high-quality mathematical discourse is necessary to increase equity and access in math education (Wilhelm et al., 2017). Cognitively demanding tasks lend themselves to be enhanced by rich,

mathematical discourse through collaboration and the co-creation of meaning. Aguirre et al. (2013) agree, "A student's correct and confident use of mathematical language and argumentation strategies, supported by positive feedback from teachers and peers, could help to reflect or shape a positive mathematical identity" (p. 16). Compared to pre-PD questionnaire responses, four of nine participants began to emphasize the use of mathematical discourse as an avenue towards equitable opportunities to learn. This is important when related to teachers' preference for procedural or conceptual understanding, as student participation in high-quality mathematical discourse has been found to be higher on average in response to cognitively demanding tasks (Wilhelm et al., 2017). Wilhelm et al. (2017) also identified a relationship between teachers' explanations for students' struggles in mathematics – students who were perceived to struggle because of inherent ability, their families, or the community were given less opportunities to participate in high-quality discourse.

According to Hammond (2015), "Too often, we focus on only doing something *to* culturally and linguistically diverse students without changing ourselves" (p. 52). As a result, educators tend to blame failure on the students themselves, as well as their environments outside of school (Gay, 2010). Culturally responsive teachers must critically reflect on their sociocultural and mathematical backgrounds and how their current beliefs and practices might reflect differing values in order to become aware of how they respond to their student based on their different experiences. Critical reflection is an essential activity when attempting to overcome deficit-oriented beliefs regarding students from low-income backgrounds and their families (Howard, 2010). Though few pre-questionnaire responses indicated engagement in critical reflection, seven participants

made critically reflective statements about their own positionalities, as well as their students', within responses after PD participation, affirming the role of critical reflection within professional learning (Durden & Truscott, 2013; McCulloch et al., 2013; Jackson & Jong, 2017). This finding is particularly interesting when participants' shift from deficit- to resource-oriented language is also taken into account as participants began to understand the backgrounds of diverse students as assets instead of deficiencies.

Implications for Professional Development and the CRME Framework

The CRME Framework was constructed to address both the pedagogical dispositions of culturally responsive math teachers, as well as their practice, in hopes of confronting inequities in students' opportunities to learn. Aguirre et al. (2013) posed three questions that researchers should ask themselves before engaging in equity work that begin to make connections between equity, access, and mathematics: What mathematics? For whom? For what purpose? The pedagogical element of the CRME Framework, based on Rubel and Chu's (2012) Culturally Relevant Mathematics Pedagogy, was used to help educators understand their own positionality and dispositions in terms of equity and mathematics. Components include (a) teaching for understanding (What mathematics?), (b) centering instruction on students' experiences (For whom?), and (c) developing students' critical consciousness with, and about, mathematics (For what purpose?). These questions must be addressed and reflected on before implementing culturally responsive practices in the math classroom.

Each participant within the present study began with a different set of experiences and beliefs about mathematics, students, and learning. As such, they experienced shifts in dispositions and attitudes towards culturally diverse student populations in different

ways, depending on their background knowledge and previous experiences, as prior research has also concluded (Wager & Foote, 2013). When implementing the CRME Framework, PD facilitators should consider the multiple perspectives and experiences of participants in order to design learning activities that address participants' areas of growth, as well as the specific needs of the district.

Each pedagogical dimension of the CRME Framework is critical in addressing inequities within mathematics classrooms. In order to teach for understanding, an educator must value and make connections between procedural and conceptual mathematics, as well as to students' prior knowledge. Without this deeper understanding, a teacher cannot address the two related Culturally Responsive Mathematics Teaching practices, the cognitive demand and knowledge depth of the tasks presented (TEACH MATH, 2012), in an equitable manner. Without centering instruction on students' experiences and connecting to their prior knowledge, students will not be able to participate in thoughtful mathematical discourse or become active participants in their own learning.

Finally, if a teacher does not find it necessary to develop students' critical consciousness with, and about, mathematics, students will not become empowered to continue fighting for equitable opportunities in their mathematics education, even after they have moved on to the next grade level. Many teachers are unaware of their own cultural and racial positionality, as well as how their students might perceive their classrooms and actions differently (Goldenberg, 2014). They may also misunderstand the consequences of taking a colorblind stance, believing that the best way to eradicate

racism is to deny the existence of race (Ullucci & Battey, 2011) and may become defensive (Battey & Franke, 2015).

Instructional leaders that choose to implement this PD for CRME or one similar should consider ways to address teachers' perceptions of sociocultural differences much earlier in the process, particularly if they refuse to acknowledge race/ethnic as a central issue in education. As I reflect on my own learning process, I realize that perhaps I was overly concerned with how participants might respond and had not fully removed my own veil of colorblindness. I could easily answer "What mathematics?" and "For what purpose?" Now, as a result of this PD and action research project, I have learned how to answer the final question, "For Whom?" To address this weakness within the PD design, I recommend using the video clip *Culturally Responsive Teaching* (Lancaster, 2015) during the first PD week as a starting point discussion instead of waiting until the second to last week. Though these topics may be difficult to broach, they are no less important as we work towards increasing the equity and access of opportunities to learn.

Implications for District Leadership

This study also has implications for school- and district-level leadership and their support for PD initiatives centered on cultural responsiveness in mathematics education. Prior research has pointed to the significant cultural and racial gaps between teachers and their students (Battey, 2013; Diggles, 2014; Gay, 2013; Goldenberg, 2014). As schools continue to become increasingly more diverse, district leadership needs to ensure that their teachers have adequate professional learning opportunities that address more than just content, classroom management, and standardized testing. Openly addressing classroom-level inequities and deficit mindsets is critical if administrators want to ensure

all students are provided with access to rigorous and relevant mathematical content in an environment designed to help them succeed.

An important aspect of the PD described in this study is the trusting relationship that was already in place prior to implementation that allowed me to ask seemingly uncomfortable and difficult questions. District leaders should be cognizant of who will be facilitating this learning to ensure they are prepared to respond accordingly to the challenges that come with initiating discussions concerning sociocultural differences and be prepared to respond accordingly. Discussions concerning power, diversity, and implicit biases can be uncomfortable, even unsettling at times (Aguirre et al., 2017), and leaders need to be sensitive to this reality when implementing professional learning designed to confront teachers' deeply held and implicit biases.

District leaders also need to develop a deep understanding of the culture within the communities they serve. Context matters, and leaders cannot support teachers in culturally responsive practices if they do not understand the cultural- and community-based resources within their students' environments – both in and out of school. Gutiérrez (2012) makes this argument especially important to mathematics – "A focus on the context of learning also serves as a humanizing tool in mathematics research" (p. 18). Leaders with a clear understanding of their community's cultural contexts and values can more readily support teachers, especially those new to the district or profession, in the implementation of the CRME Framework.

Suggestions for Future Research

This study examined the PD experiences of elementary math teachers within a midsized rural district as they engaged in discussions, reflections, and other CRME-based

activities to increase their understanding of equity in mathematics education, as well as within their individual classrooms. As a former high school math teacher and instructional coach, my experiences lead me to believe that implementing this PD with secondary math teachers might offer a different perspective based on their mathematical, as well as sociocultural, backgrounds. The National Center for Education Statistics (2018) confirms that 35% of high school math teachers nationwide are male as compared to only 10.1% of elementary teachers. Future research could explore the influence of PD for cultural responsiveness that includes math teachers K – 12, rather than elementary or secondary, within a single district to gain a fuller understanding of the current state of equity and mathematics education.

While this study did include data collected from classroom observations to gather evidence of teachers' classroom practice, it was minimal in comparison to the bulk of data collected from questionnaire responses and PD and interview transcripts. This limitation partially stems from time constraints at the end of the school year, as the observation phase began with only a few weeks left before teacher contracts ended. Additionally, classroom observational data was not collected prior to PD participation, so evidence did not document whether teachers experienced a change in instructional practice. Future studies might include a greater focus on the changes in practice that result from PD for CRME. Data collection could also extend to student performance or achievement data, particularly in the area of action research, to determine the effectiveness of teachers' culturally responsive classroom practices.

Finally, further research is needed concerning instructional leaders themselves in terms of how they interpret the community and cultural context of their schools and

districts and how, if at all, they engage in equity work. How do their mathematical and sociocultural backgrounds influence their understanding of equity in math education? How do they understanding the community within which they are employed? What if an instructional leader's vision for instructional improvement is not aligned with the mandates that often come with test-based accountability? Future research needs to address the challenges associated when equity work in mathematics conflicts with state and district expectations for accountability.

Conclusion

> *"I know how strange it can sound to say that math literacy – and algebra in particular – is the key to the future of disenfranchised communities, but that's what I think, and believe with all of my heart"* (Moses & Cobb, 2001a, p. 5).

Chapter 1 began with a quote from a study participant after reading an article about Bob Moses' comparison of math literacy to the civil rights movement. The dialogue between two participants continued – "We need people to flip hamburgers, too. We need that. There's a demand for people without college degrees right now," one participant insisted. A second participant, offering another perspective, replied,

> I don't think Moses meant that everybody *has* to go to college. But if you live in a home where your parents didn't get a college education, does that automatically mean that you should also not go to college, or should you still have access to the opportunity? He's not saying that everybody has to go, but [not all people] have access to the same kind of information.

The first participant paused, thinking, then said, "So…what you're saying is that it is more about opportunity." "Right," confirmed the second participant, nodding her head.

"It's more about ensuring access to an opportunity for students who would not have it otherwise. If your parents can't read, and nobody helps you learn how to read... it doesn't mean you *can't* do it. It means you haven't had the opportunity to learn yet." The first participant responded in agreement, "Then there are those people who will always be given more opportunities…so regardless of their ability, they start way up here!"

There is a false dichotomy that continues to exist between equity work and mathematics education (Aguirre et al., 2017). This is partially attributable to the limited, if any, emphasis on content-specific equity work provided by teacher education programs for future teachers (Rubel, 2017). Until preservice teacher preparation catches up, it is up to school and district instructional leaders to ensure that their teaching force understands that all of their students are capable of high levels of achievement when given access through equitable instructional practices.

Participants' prior experiences with learning mathematics, as well as their exposure to cultures outside of their own, influenced their beliefs about who is capable of learning mathematics and what mathematics is worth knowing. Analysis of the language used within their questionnaire responses from before and after PD participation revealed a decrease in use of deficit-oriented language, increase in resource-oriented language, greater appreciation for conceptual, context-specific mathematical understanding, and a new emphasis on mathematical discourse as a critical opportunity to learn. These findings suggest that elementary math teachers, particularly those working in diverse school settings, can benefit when given time and space to critically reflect and discuss their beliefs about their students and math education, and how these beliefs can impact equity and access within their classrooms.

Like Bob Moses, we teachers must take up the cause of those children who are so often dismissed by the system. That means never giving up on them; refusing to accept failure; being their advocates and pushing them and the systems that block their success. It also means having the courage to find like-minded people—on faculties, in the community, wherever they may be—and joining together to do this difficult work. One person cannot change the world alone. We all have to step out of our personal comfort zones to create courageous, united efforts. (Delpit, 2012, p. 4)

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Appendix A

Participant Questionnaire

Beliefs Regarding Culturally Responsive Mathematics Education Questionnaire

1. Please provide your race/ethnicity, number of years of teaching experience, and whether you teach Kindergarten – 2nd grade or 3rd – 5th grade this year.

2. In your opinion, what does it mean to teach mathematics for understanding?

3. What does it mean to "know" math? How can you tell when your students "know" the math you are teaching them?

4. In what ways, if at all, do/might the sociocultural identities (e.g. race, language, class, culture, gender, etc.) of the **students** you teach inform your decisions about creating and teaching math lessons?

5. In what ways, do/might **your** sociocultural identities (e.g. race, language, class, culture, gender, etc.) inform your decisions about creating and implementing math lessons?

6. Is getting to know your students' families and becoming familiar with their communities useful for teaching mathematics? Why or why not?

7. What role, if any, do social issues (i.e. issues in the school and local community) play in the learning and understanding of mathematics?

8. In your own words, explain what it means to address issues of equity and access as you plan and implement mathematics instruction.

9. Why is it important for students to learn mathematics?

Appendix B
Interview Protocol

Semi Structured Interview Protocol

Protocol for Research Question #1:
How do math teachers' cultural backgrounds and previous experiences with mathematics contribute to their understanding and approach to equity and access in math education?

1. How does the way you teach math now compare to the way you were taught mathematics as a student?

2. What aspects of your own history with learning mathematics do you think have an impact on your views about teaching mathematics?

3. Reflecting on your own experiences, what do you believe are the critical components for mathematics success? How are these reflected in your instructional practice?

Protocol for Research Question #2:
How does professional development in culturally responsive mathematics education influence teachers' understanding and use of equitable teaching practices?

1. How would you describe mathematics teaching that is culturally responsive? How was this affected, if at all, by the PD?

2. In thinking about the PD activities, how those activities/discussions resonated and/or challenged your thinking about mathematics teaching in culturally responsive ways? Please share some of your insights or experiences.

3. What challenges have you faced in teaching mathematics this year? When you think about teaching mathematics in culturally responsive ways, are these challenges similar? Different?

4. How, if at all, has this PD affected your lesson planning? Your instruction?

UNIVERSITY of HOUSTON

DIVISION OF RESEARCH
Institutional Review Boards

APPROVAL OF SUBMISSION

May 2, 2018

Lauren Hobbs

Dear Lauren Hobbs:

On May 2, 2018, the IRB reviewed the following submission:

Type of Review:	Initial Study
Title of Study:	Developing Culturally Responsive Mathematics Teachers: Understanding Equity and Access in Math Education
Investigator:	Lauren Hobbs
IRB ID:	STUDY00000965
Funding/ Proposed Funding:	Name: Unfunded
Award ID:	
Award Title:	
IND, IDE, or HDE:	None
Documents Reviewed:	• Hobbs Study Protocol, Category: IRB Protocol; • Classroom Observation Protocol.pdf, Category: Study tools (ex: surveys, interview/focus group questions, data collection forms, etc.); • Math Autobiography Reflection Questions, Category: Study tools (ex: surveys, interview/focus group questions, data collection forms, etc.); • Research Timeline, Category: Other; • Pre- Post-PD Questionnaire, Category: Study tools (ex: surveys, interview/focus group questions, data collection forms, etc.); • District Letter of Approval.pdf, Category: Letters of Cooperation / Permission; • Interview Questions, Category: Study tools (ex: surveys, interview/focus group questions, data collection forms, etc.); • Recruitment Letter, Category: Recruitment Materials; • Consent Document- Non Clinical, Category:

	Consent Form;
Review Category:	Expedited
Committee Name:	Not Applicable
IRB Coordinator:	Danielle Griffin

The IRB approved the study from May 2, 2018 to May 1, 2019, inclusive.

To ensure continuous approval for studies with a review category of "Committee Review" in the above table, you must submit a continuing review with required explanations by the deadline for the April 2019 meeting. These deadlines may be found on the compliance website (http://www.uh.edu/research/compliance/). You can submit a continuing review by navigating to the active study and clicking "Create Modification/CR."

For expedited and exempt studies, a continuing review should be submitted no later than 30 days prior to study closure.

If continuing review approval is not granted on or before May 1, 2019, approval of this study expires and all research (including but not limited to recruitment, consent, study procedures, and analysis of identifiable data) must stop. If the study expires and you believe the welfare of the subjects to be at risk if research procedures are discontinued, please contact the IRB office immediately.

Unless a waiver has been granted by the IRB, use the stamped consent form approved by the IRB to document consent. The approved version may be downloaded from the documents tab.Attached are stamped approved consent documents. Use copies of these documents to document consent.

In conducting this study, you are required to follow the requirements listed in the Investigator Manual (HRP-103), which can be found by navigating to the IRB Library within the IRB system.

Sincerely,

Research Integrity and Oversight (RIO) Office
University of Houston, Division of Research
713 743 9204
cphs@central.uh.edu
http://www.uh.edu/research/compliance/irb-cphs/

Appendix C

Classroom Observation Protocol

Culturally Responsive Mathematics Education
Classroom Observation Protocol

Teacher: _____# of Students in Classroom: _____
Date of Observation: _____ Start Time: _____ End Time: _____
After a classroom observation, review field notes for evidence of each equity-based practice rooted in CRME. If evidence is found, note it in the "Evidence" column.

EQUITY-BASED PRACTICE: Cognitive Demand

Observable Indicator	Examples	Non-Examples	Evidence
The teacher **presents tasks with high cognitive demand, exploring and analyzing multiple solution strategies/ representations.**	Teacher uses high-level, challenging questions Assignments require analysis and justification Teacher uses critical thinking techniques such as requesting evidence, accepting multiple points of view, respecting divergent ideas Teacher consistently demonstrates high expectations for academic achievement	Tasks have low cognitive demand, emphasizing a single strategy Students must follow procedures step-by-step, or memorize facts Presents the belief that there is one best/right way to view problems Teacher has low expectations (consistently gives work that is not challenging)	

EQUITY-BASED PRACTICE: Depth of Knowledge and Understanding

Observable Indicator	Examples	Non-Examples	Evidence
The teacher **structures activities to make student thinking/understanding evident.**	Students are encouraged to evaluate their own products Teacher requires multiple ways to demonstrate knowledge (language, pictures, models, concrete objects, etc.) Students explain, reason, and argue to demonstrate understanding Teacher discourages linking speed with intelligence	Teacher discourages mistakes and immediately corrects them, often without constructive feedback Teacher promotes memorization without examination and shallow understanding Teacher uses standardized testing or constant quizzing; no assessment alternatives Teacher connects math ability with correct answers and speed	

EQUITY-BASED PRACTICE: Mathematical Discourse and Communication

Observable Indicator	Examples	Non-Examples	Evidence
The teacher **creates opportunities for rigorous and meaningful discourse and co-constructing meaning.**	Teacher has structures in place that promote student talk, e.g., think/pair/share, small group work, partner work Teacher utilizes collaborative learning to allow collaborative discourse Students are invested in their own and others' learning	Classroom is arranged for quiet, solitary work only Students are never encouraged to assist their peers Teacher doesn't balance student participation	

EQUITY-BASED PRACTICE: Power and Participation

Observable Indicator	Examples	Non-Examples	Evidence
The teacher **positions students as sources of expertise, valuing all students' contributions.**	Teacher values multiple answers to a problem/task and multiple ways to find answers Students do not hesitate to ask questions that further their learning Students are encouraged to respond to one another positively	Teacher ascribes math authority to the teacher or textbook and dominates decision-making Teacher stays behind desk or across table from students; s/he does not get "on their level" Teacher does not address negative comments of one student towards another	

EQUITY-BASED PRACTICE: Academic Language Support for ELLs

Observable Indicator	Examples	Non-Examples	Evidence
The teacher **provides scaffolded language supports.**	The teacher prioritizes mathematical meaning-making, not "correct" use of English The teacher uses a variety of language strategies throughout the lesson, including gestures, visuals, manipulatives, graphic organizers, etc.	No language supports are evident. Teacher requires students to use the same discourse (standard English) in all social contexts (e.g., lunchroom, playground) Teacher discourages students' use of home language, even when its	

	The teacher responds positively to children's use of home/native language/dialect	use is appropriate to the situational context	

EQUITY-BASED PRACTICE: Culture- and Community-Based Funds of Knowledge

Observable Indicator	Examples	Non-Examples	Evidence
The teacher **makes intentional connections to multiple knowledge resources to support math learning (math, culture, language, family, community).**	Community-based projects are included in the planned program Teacher makes reference to familiar careers, backgrounds, daily activities during instruction Teacher addresses real life problems and issues within the students' communities and respects their "funds of knowledge" Real-world examples that connect to students' lives are included in the curriculum	Learning experiences are derived almost exclusively from published textbooks and other materials that do not relate to the classroom community or the larger community being served No evidence of home/family connections in the classroom No attempt is made to link students' realities lesson Learning experiences are disconnected from students' knowledge and experiences	
The teacher **uses previous math knowledge as a bridge to new math understandings.**	Teacher communicates real-world, familiar connections to new math concepts Teacher makes references to previously learned math content. Teacher builds new learning from familiar concepts to make connections	Makes statements such as "They lack skills" or "they don't know any math" No effort made to establish relationships with caregivers; there's evidence of a "deficit perspective" in which families and caregivers are viewed as inferior Teacher tends to blame parents/home for lack of student achievement	
The teacher **engages students in identifying and developing solutions that**	Teacher encourages students to question social structure (the "way things are") Teacher uses learning activities that encourage	Teacher never engages students in dialogue about the issues being raised Teacher primarily presents content, curriculum, and ideas that	

address social injustice(s).	students to reflect on discrimination/bias Teacher engages students in critical examination of curriculum content and personal experiences that contribute to equity or inequity among individuals or groups in society	are representative of middle/upper class perspective(s) Teacher does not encourage application to real-world issues; accepts the status quo by ignoring real life problems related to the math being studied	