UNIVERSITY OF CALIFORNIA SAN DIEGO
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Bringing the Culture to Mathematics: The Impact of Lesson Studies on Math Teachers' Understanding and Self-Efficacy of Culturally Relevant Pedagogy

A dissertation submitted in partial satisfaction of the requirements for the degree Doctor of Education

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by

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The dissertation of Curtis A. Taylor is approved, and it is acceptable in quality and form for publication on microfilm and electronically:

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VITA

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ABSTRACT OF THE DISSERTATION

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Doctor of Education in Educational Leadership

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African-American and Latinx students are losing out on opportunities to take part in high-paying careers and higher education because of a lack of mathematical proficiency. The institutional and individual factors that are present in K-12 school systems create feelings of alienation and disidentification in African-American and Latinx students from math. The most prominent being the inequitable math experiences that are prevalent in low-income schools where minority students make up the majority. Failing to provide African-American and Latinx students with a mathematics curriculum and instruction centered on their experiences, culture, and traditions is a deterrent to the achievement of equity in mathematics education. Culturally Relevant Pedagogy in mathematics builds on students' cultural capital, prior knowledge, and

mental schemas that supports African-American and Latinx students to acquire academic success, cultural competence, and sociopolitical awareness. However, educators do not possess a depth of understanding and/or the self-efficacy to implement culturally relevant pedagogy into their math classrooms. Lesson studies, a system of collaborative efforts and live instruction, is a promising professional development model that addresses this issue. This study utilized a mixed method approach to understand how lesson studies impacted three middle school math teachers' competency in culturally relevant pedagogy by exploring: (1) In what ways does the lesson study model help teachers gain a better understanding of culturally relevant pedagogy? (2) In what ways does the lesson study model support teachers in creating, refining, and analyzing culturally relevant, cognitively demanding mathematical tasks? And, (3) In what ways does the lesson study model support teachers in deciding on effective pedagogical moves?

CHAPTER ONE: INTRODUCTION

Statement of the Problem

"*Today, I want to argue [that] the most urgent social issue affecting poor people and the people of color is economic access. In today's world, economic access and full citizenship depend crucially on mathematics and scientific literacy. I believe that the absence of math literacy in urban and rural communities in this country is an issue as urgent as the lack of registered Black voters in Mississippi was in 1961."* - Robert Moses (2001), Radical Equations

The above quotation from Robert Moses resonates about how powerful math literacy contributes to the advancement of life for individuals. In particular, science, technology, engineering, and mathematics (STEM) careers are vital for the economic growth of the United States. STEM workers drive our nation's innovation and competitiveness through the creation of jobs, companies, and industries (Langdon, McKittrick, Beede, Khan & Doms, 2011). Unfortunately, the United States is behind in producing qualified individuals for these careers. The lack of STEM professionals is in part due to the consequence of the low rate of minority and female undergraduate majors, and graduates, in this academic discipline (Beasley & Fischer, 2012). As STEM workers are influential to the creation of many of our future innovations, it is imperative that we have representation from all racial groups.

The underrepresentation of African-Americans and Latinos in STEM is exceptionally noticeable. According to Landivar (2013), the racial makeup of the STEM workforce in 2011 consisted of 70.8% White (non-Hispanic), 14.5% Asian, 6.4% African-American, and 6.5% Hispanic or Latinx. These are unsettling statistics as African-American and Latinx populations are steadily increasing. The U.S. Census Bureau (2015) projects that by the year 2060, minorities will comprise 56.4% of the population and minorities under 18 will be 64.4%. The vast quantity of educational statistics on STEM interest attributes the amount of racial disparity in STEM to the inequities in primary and secondary schools (Beasley & Fischer, 2012).

To understand this leaky STEM pipeline, we must begin at the foundation, our K-12 school systems. Most notable within our low-income schools we see this as a prominent issue. During the 2014 - 2015 school year, the national average of students who attended a high-poverty school, schools with 75% or more of students on Free and Reduced Lunch (FRDL), was 24%. Out of that 24%, Latinx and African-American students composed 46% and 45% of the enrollment, respectively (National Center for Education Statistics, 2017). Research results in the area of educator racial identification found that low-income schools are predominantly served by White educators. Some of these White teachers bring with them an unconscious bias which influences their teaching and learning process from a deficit perspective. Specifically, their views of underrepresented students' abilities to perform academically at a high level of achievement is limited in belief and harmful. These misperceptions are then acted out through acts of microaggressions that have been shaped by stereotypes and unconscious biases with the potential to impact the performance metric they may possess about students of color (Allen, Scott, & Lewis, 2013; Delpit, 2012; Walker, 2011). Moreover, literature suggests that low teacher quality and inadequate mathematics and science curriculum and instruction are additional contributing factors that inhibit African-American and Latinx students interest and pursuit of careers such as STEM at low-income schools (Battey & Leyva, 2016; Berry, Ellis, & Hughes, 2014; Bolyard & Mayer-Packenham, 2008; Delpit, 2012; Goldhaber, Lavery & Theobald, 2015; Ladson-Billings, 1997; Smith, Trygstad, & Banilower, 2016). As STEM jobs are consistently growing, African-American and Latinx students are missing the opportunity to take part in such careers from the lack of proficiency in mathematics.

Mathematics is regarded as a gatekeeping subject that allows for successful pursuit and persistence in high-earning careers such as STEM (Lubienski, 2002). Disaggregated data

indicates that African-American and Latinx students are performing lower in math compared to their counterparts. The National Assessment of Educational Progress (NAEP) Long-Trend Study confirmed that African-American and Latinx 4th, 8th, and 12th grade students underperform in math at a higher level compared to their White peers in amounts, equal to 74% and 66% standard deviation, respectively (Dee, 2015; Lubienski, 2002; Rampey, Dion & Donahue, 2009; Tate, 1997). It is even more startling as 12th grade Latinx and African-American students are performing as well as 8th grade White students on the NAEP's mathematics assessment (Flores, 2007; Lubienski, 2002). Trends examined in an International Mathematics Study (2011) also distinguish the gap in math performance between low-income schools, where minority students make up the majority, and high-income schools. Results suggested that eighth grade students in California schools with 10% or less of students on FRDL scored 69 points higher in mathematics than schools with 75% or higher of students on FRDL. Because of such discrepancy in achievement levels, for our students of color, mathematical literacy is that of a civil rights issue (Moses & Cobb, 2001; Ladson-Billings, 1997).

According to Brown-Jeffrey (2009), "Race, gender, and social class are the source of much of the inequity that exists in American society. Race, gender, and socioeconomic differences in math begin early and continue throughout the educational experience" (p. 391). The role of mathematics in schools has been one of promoting racial stratification and elitism (Boaler & Staples, 2008; Battey, 2013; Ladson-Billings, 1997). For example, the discriminatory tracking of math courses that is found in U.S. schools places many African-American and Latinx students in lower math tracks. Such discriminatory practices, and the lack of proficiency in mathematics present from early grades, exclude African-American and Latinx students from opportunities that advanced mathematics coursework offers students. Research has found that

completion of advanced math courses has a positive effect on college graduation and earnings later in life (Battey, 2013; Byun, Irvin & Bell, 2015; Rose & Betts, 2001). Byun et al. (2015) posits that 73% of students who completed a sequence of advanced math courses (algebra 2, geometry, precalculus, and/or calculus) enrolled in a 4-year college compared to 23% who did not take advanced math courses. High school students, who completed algebra, expected an increase in earnings by 3.2% and those who completed calculus expected a 7% increase (Rose & Betts, 2001). These opportunities seem to be afforded to many White and Asian students as many of the higher mathematics tracks, such as Advanced Placement (AP) courses, find White and Asian students to be more prominent (Boaler, 2016; Battey, 2013).

As our nation is becoming much more culturally and linguistically diverse, mathematics teaching has been slow to change. Mathematics teaching continues to expose students to a banking pedagogy (Tutak, Bondy & Adams, 2010) where teachers dispense out the procedural understanding of mathematics, and simply have students repeat what they have been shown. This type of teaching is most prominent in urban, low-income schools. Such direct teaching denies many students from opportunities of critical thought and problem-solving in which will prepare them to use mathematics as a tool to negotiate the complex democratic processes of the United States (Delpit, 2012; Jackson, 2013; Tate, 1995). African-American and Latinx students fail in school not because their teachers do not know the content, but because their teachers cannot create connections between the math content and their students' existing mental schemas, prior knowledge, and cultural perspectives (Irvine, 2003). Failing to provide African-American and Latinx students with a mathematics curriculum and instruction centered on their experiences, culture, and traditions is a deterrent to the achievement of equity in mathematics education (Tate,

1995). There is a necessity to provide mathematics curriculum and instruction in which students of color see themselves within the mathematics as they obtain mathematical literacy.

Culturally Relevant Pedagogy and Mathematics

The role of curriculum in the United States has been identified as a tool to enforce cultural assimilation to a Eurocentric paradigm that White educators find desirable (Jackson, 2013; Zamudio, Russell, Rios & Bridgeman, 2011). Such hegemonic curriculum impacts African-American and Latinx students' performance in math. A curriculum that does not connect in positive ways to a students' culture is doomed to fail (Delpit, 2012). Culture is an individual's structure of knowing, understanding, acting and being in the world (Ladson-Billings, 1997). Because culture informs our thoughts and actions, educators must understand the importance of learning their students' native cultures to design culturally responsive and student-centered instruction (Rodriguez, Jones, Pang & Park, 2004). Culturally Relevant Pedagogy (CRP) integrates students' cultural capital into the curriculum. In Ladson-Billings' (1995a, 1995b) seminal work, she posits that CRP would create three impacts (the basic tenets of CRP): produce academic achievement in students, produce students who demonstrate cultural competence, and develop sociopolitical consciousness in students. The culturally responsive classroom creates opportunities for students to socialize and grapple with the curriculum, build teacher-student relationships that are equitable and reciprocal, and encourage a community of learners rather than competitive, individual achievement (Ladson-Billings, 1995b).

Teaching math that is relevant, engaging, and applicable to everyday life has long-reaching promotive impacts on math beliefs of African-American and Latinx students (Diemer, Marchand, McKeller & Malanchuk, 2016; Delpit, 2012; Gutstein, 2003; Malloy, 2009). Research suggests that African-American and Latinx students benefit from classrooms that

implement complex instruction, heterogeneous grouping, and open-ended and inquiry-based mathematics (Boaler, 2008; Boaler & Staples, 2008; Gholson & Wilkes, 2017; Stinson, 2013). But, students of color, who are predominantly found in low-income schools, need instruction that allows for them to utilize their culture and investigate the inequities that are present in their communities. This pedagogical stance could help create a solid mathematical identity in African-American and Latinx students. African-American and Latinx students greatly benefit from math instruction that incorporates a CRP design (Delpit, 2012; Gutstein, 2003; Irvine, 2010; Ladson-Billings, 1995a, 1995b, 1997). But, there is a gap in the research that does not provide a significant understanding of how CRP impacts students of color mathematical knowledge and engagement. Also, what is missing is a pedagogical tool that would help educators to enact CRP in mathematics, analyze, and reflect on the practice within a learning community.

Research Questions

This study explored the experiences of three middle school teachers in the High Tech High organization of schools as the teachers engaged in a lesson study model that allowed for them to learn how to create and implement more culturally relevant, cognitively demanding mathematical tasks into their practice. A unique part of this study investigated if such tasks were impacting students' knowledge and engagement. To this end, the following research questions were investigated in this study using a design-based research method:

1. How does the use of lesson studies help teachers to implement effectively Culturally Relevant Pedagogy in their mathematics classroom?
    a. In what ways does the lesson study model help teachers gain a better understanding of culturally relevant pedagogy?

b. In what ways does the lesson study model support teachers in creating, refining, and analyzing culturally relevant, cognitively demanding mathematical tasks?
c. In what ways does the lesson study model support teachers in deciding on effective pedagogical moves?

2. What is the impact of using culturally relevant, cognitively demanding mathematical tasks on African-American and Latinx students' mathematical knowledge and engagement?

Overview of the Study

This study utilized a mixed-methods approach to understand how the professional development model of lesson study helped teachers to understand and implement Culturally Relevant Pedagogy in their mathematics classroom, and how culturally relevant, cognitively demanding math tasks impacted African-American and Latinx students' mathematical knowledge and engagement. The study followed an intervention design and explored teachers' attitudes and experiences as they engaged in the lesson study model to learn how to take their existing mathematics curriculum, identify core mathematical ideas, and create culturally relevant, cognitively demanding mathematical tasks. Also, the study sought out the impact of such mathematical tasks on students of color's math knowledge and engagement. This study took place within a public, charter middle school that serves a diverse student population in San Diego, California. A total of 3 teachers participated in this study. Data were collected throughout the lesson study cycles in forms of pre- and post-focus group for teachers, teacher interviews, critical reflection journals, audio/video recording of each lesson study cycle, and any artifacts produced throughout each cycle. Pre- and post-focus group data and teacher interviews were

collected to determine how teachers' understanding and self-efficacy shifted through the lesson study model. A unique component of this study was to understand how CRP impacts students' knowledge and engagement. To document such experiences data was collected from students in the form of pre- and post-tests after each lesson and classroom observations of engagement. Classroom observation data, critical reflection journals, and documentation produced throughout the lesson study cycles were used to corroborate focus group and interview data.

Significance of Study

This study explored how teachers implement culturally relevant pedagogy in mathematics classrooms through the use of lesson studies. Specifically, this study sought to understand how teachers used an existing curriculum and modified mathematical tasks to be more culturally relevant and cognitively demanding, and how such mathematical tasks impacted students' mathematical knowledge and engagement. Results of this study provide additional insights into the practice of CRP and mathematics that create rich and deep mathematical experiences. Also, the importance of connecting students' prior knowledge, experiences, and culture to impact student engagement and acquisition of mathematical concepts. In addition, it provides support for lesson studies as a professional development model that increases teachers' pedagogical and content knowledge.

Overview of Dissertation

In chapter 1, I have introduced the problem, outlined the research study, and discussed the significance of the study. Chapter 2 includes a review of relevant literature, including the institutional and individual factors that impact the math achievement of African-American and Latinx students. In chapter two, Critical Race Theory (CRT) will be a lens used to provide critique of addressing racial inequalities found in K-12 school systems. This chapter will also

examine how schools and teachers impact African-American and Latinx students' achievement through the ideology of colorblindness and the lack of quality teachers and instruction found in low-income schools. This is followed by an exploration of how African-American and Latinx students internalize such experiences and its effects on their math achievement. Accordingly, the benefits and challenges of providing students with culturally relevant mathematics instruction are examined. I conclude chapter two with an overview of lesson studies, a collaborative professional development model that will help promote CRP in mathematics classrooms. In chapter three, I outline a design-based approach that utilized quantitative and qualitative methods to explore how teachers are understanding and developing their sense of self-efficacy of CRP in their math instruction, and how this impact students' mathematical knowledge and engagement. In chapter four I share the results of my data analysis, presenting evidence from the pre- and post-focus group, teacher interviews, classroom observations, and document analysis, as well as pre- and post-tests from each implemented lesson. In chapter five, I discuss the key takeaways from the study, the implications for culturally relevant pedagogy in the math classroom as well as the implications for the use of lesson studies as a professional development model, and areas for future research.

CHAPTER TWO: LITERATURE REVIEW

Background

On the 2015 Programme for International Student Assessment (PISA), the United States ranked 31st in mathematics out of the 35 participating OECD countries (Organisation for Economic Co-operation and Development, 2016). If we are to disaggregate the data based upon race/ethnicity on the PISA, we are to find a distinct achievement gap in mathematical literacy with students of color in the United States. On the 2015 PISA, the following scale average scores are recorded: Whites (499), Black/African-American (419), Hispanic/Latino (446) and Asian (498). According to the 2017 NAEP Mathematics Report Card, African-American and Latinx students show that mathematics performance has improved through the years, but we find that there is still a significant gap between African-American and Latinx students' mathematics performance compared to their White and Asian peers (National Center for Education Statistics [NCES], 2015; Nation's Report Card, 2017). A similar gap is noticeable on the California Assessment of Student Performance and Progress (CAASPP) 2017 Smarter Balanced test results, which finds that the percentage of African-Americans and Latinx students who met/exceeded the state standards were 17.58% and 23.62%, respectively. In contrast, 51.35% Whites and 73.36% Asians met/exceeded the state standards on the same exam. If things are improving, why is there still such a persistent gap?

African-American and Latinx students constitute the two largest ethnic minority groups in U.S. schools. Yet, the academic achievement in mathematics of such groups has been dismal for decades (Howard, 2003). As to avoid "gap-gazing" (Guiterrez, 2008), which continues the perception that African-American and Latinx students are inferior in intellectual capacity to their White and Asian peers, much of this lack of achievement is due to an educational debt. African-

Americans and Latinos have a history of being denied a free and equal education in the United States (Battey, 2013; Darling-Hammond, 2004; Ladson-Billings, 2006). This educational debt (Ladson-Billings, 2006) dates as far back as slavery for African-Americans in which the right to an education was forbidden. During the period of segregation, and even through the twentieth to the present twenty-first century, African-Americans and Latinos have attended schools that lacked the quality and resources that White students have been afforded (Darling-Hammond, 2004). This is still a prominent issue today as there is an inequitable distribution of public funds per student in districts that are strikingly different in racial composition (Battey, 2013; Darling-Hammond, 2004; Ladson-Billings, 2007). In the case of Latinos, educational disparities are documented in historic segregation cases such as *Mendez v. Westminster* (1946) and the Lemon Grove Incident (Ladson-Billings, 2006). These historic events have placed African-Americans and Latinos at a disadvantage compared to their White peers especially in the content subject of mathematics.

The Role of Teachers' Attitudes Towards Students of Color Math Achievement

The belief that the United States has entered a post-racial American society has presented us with an opportunity to discuss the elements of racism, especially its influence within our educational institutions. Racial ideology has moved from overt actions of marginalization to a tone of colorblindness, which explains many of today's ethnic inequalities. Colorblindness suggests that race is no longer an issue. Cultural differences between people are seen as not important or relevant because the norm for society is to assimilate or acculturate to an American value system. However, a lack of diversity, equity and inclusive thought hinders the effort of various racial groups to flourish as competent human beings. This explains an important aspect regarding the differences in achievement between White, African-American and Latinx students

(Bonilla-Silva, 2014). White students enter an academic environment that supports their ways of being, while African-American and Latinx students struggle to make sense out of how to achieve academically and socially (Delpit, 2012; Ladson-Billings, 1997; Zamudio, Russel, Rios & Bridgeman, 2011). Consequently, colorblindness supports Whiteness in schools and classrooms such to maintain the social order institutionally without the appearance of being racial (Battey & Leyva, 2011). Also, the idea of colorblindness in schools invite microaggressions (Sue et al., 2007), teacher perceptions often fueled by deficit-based mindsets (Allen, Scott, & Lewis, 2013; Battey & Leyva, 2016; Delpit, 2012; Diamond, Randolph, Spillane, 2004; Walker, 2011), and unconscious stereotyping (Battey & Leyva, 2016; Beasley & Fischer, 2012; Steele, 1997).

Microaggressions. African-American and Latinx students do experience various degrees of racism throughout their K-12 years. Overt racism, such as those witnessed in the Jim Crow era, has become less apparent. However, the ideology of colorblindness has ushered in increased covert racism, which manifests as microaggressions (Sue et al., 2007). Microaggressions are brief, daily, verbal, behavioral whether intentional or unintentional, actions that communicate negative racial slights and insults toward people of color (Allen et al., 2013; Sue et al., 2007; Suaraz-Orazco, Martin, Katisficas, Cuellar, Smith & Dias, 2015). Microaggressions may not always be apparent by the perpetrator but have a powerful effect on the recipient (Sue et al., 2007). This author posits that microaggressions exist in three forms: microassault (explicit racial derogation such as name-calling), microinsults (subtle snubs that conveys a hidden message to a person of color), and microinvalidation (communication that excludes or negates the feelings or thoughts of a person of color). Continuous exposure to microaggressions can be damaging and over time function as a psychological assault on African-American and Latinx students (Delpit 2012; Sue et al., 2007). This, in turn, leads African-American and Latinx students to exhibit

actions of hiding or “acting out” to protect themselves, causing adults and peers to further criticize or marginalize them within the school (Delpit, 2012).

K-12 schools are essential in nurturing students’ academic attainment and identity development. Unfortunately, schools and districts are conduits of racial microaggressions as they often transmit socio-cultural messages that perpetuate students’ feelings of inferiority, and when internalized on an unconscious level impacts a student’s well-being (Allen et al., 2013). Such an impact could lead to depression, anxiety, and issues of self-esteem. Beasley and Fischer (2012) found that Latinx students who experience high levels of psychosocial stress, caused by racial antagonism, are more likely to have anxiety and perceive themselves as less competent academically. The idea of Whiteness in schools restrict students of color from handling these microaggressive experiences in ways emotionally without being viewed as argumentative, angry, aggressive, and other adverse associations (Battey & Leyva, 2016).

Microaggressions are detrimental to a student’s self-concept and positive racial identity development (Allen et al., 2013). A student's intelligence is the focal point of many microaggressions. Suarez-Orozco et al. (2015) illuminates a compelling comparison of microaggressions to toxic raindrops, which over time affect a victim’s well-being as well as produce a toxic classroom environment. Through a quantitative analysis of microaggressions in community college classrooms that served high concentrations of racial/ethnic minority students the instructors, majority White, initiated microaggressions. The researchers found that there was an absence of microaggressions observed between student to teacher, but found that student-to-student microaggressions to be prevalent in classrooms in which the teacher expressed such acts of covert racism (Suarez-Orozco et al., 2015). Microaggressions perpetuated by the classroom teacher may lead to a transmittance of student-to-student level microaggressions in the classroom

(Allen et al., 2013). In majority-minority, low-income schools, educators need to be mindful of the entire composition of their student identities and be aware of phrases and attitudes might have on the cognitive functioning and performance of students in their classrooms (Tine & Gottlieb, 2013).

Teacher Perceptions. Students of different ethno-racial backgrounds respond in various ways to the sociocultural context of their schools (Booth, Abercrombie, & Frey, 2016), and teacher perceptions of students are key to developing these school contexts. Teacher perceptions are formed through a teacher's belief(s) about students' abilities, capabilities, and the expectations they hold about African-American and Latinx students within an educational setting (Allen et al., 2013). All students hope to be treated equally by their teachers regardless of their race, ethnicity, and socioeconomic status (SES); however, research has indicated that teachers' perceptions can negatively affect student performance (Allen et al., 2013; Delpit, 2012; Diamond, Randolph, & Spillane, 2004; Walker, 2011). The U.S. Department of Education (2016) reported during the 2011–2012 school year that 82% of public school teachers were White. As previously noted, many low-income schools have more White teachers teaching than teachers of color. Research has found that students of color taught by White teachers receive much more negative feedback on academic performance and behavior. Some scholars argue that White teachers are not the only ones who communicate such feedback. Teachers of color, who do not possess a high sense of responsibility of their students of color learning, pose a threat to their students' academic performance as well (Diamond et al., 2004; McGrady and Reynolds, 2013; Walker, 2011). Therefore, these teachers have high expectations for Asian American students, relative to White students, and lower expectations for African-American and Latinx students (Diamond et al., 2004; McGrady and Reynolds, 2013).

It has been suggested that stereotypical views of various racial groups indicate that African-American and Latinx students are more susceptible to deficit thinking from their teachers. Deficit thinking blames poor, minority students and their families for the lack of school readiness and the disadvantages that students face in schools (Allen et al., 2013; Walker, 2011). Teachers, who possess a deficit view, respond to low academic achievement levels of minority students to uninvolved families and, even worse, the belief that minority students are intellectually inferior to their White and Asian counterparts. For example, Whites and Asian-Americans are looked to be at the top of the hierarchy of mathematical ability, and these classrooms may operate in ways that correlate with these assumptions (Battey & Leyva, 2016). Deficit perspectives about students of color and their mathematics ability stem from ideas of Whiteness. Students of color are viewed as illegitimate members in the math classroom resulting in poor relationships with teachers, lower quality of math instruction, and dis-identification with the respective supports (Battey & Leyva, 2016). Teachers, who may possess stereotypical views or biases, promote an even more significant threat to the cognitive performance of students of color in math (Delpit, 2012; Steele, 1997).

Stereotype Threat. A significant contributing factor influencing the low achievement of African-Americans and Latinx students in mathematics is the theory of stereotype threat. Stereotype threat takes place when a socio-psychological threat arising from a situation or activity perpetuates a negative stereotype with a student's racial group (Beasley and Fischer, 2012; Steele, 1997). Stereotype threat negatively affects students of color academic performance and self-efficacy in a much more alarming way. Steele (1997) posits that through prolonged exposure to negative stereotypes, members of the prejudiced-against group internalize such stereotypes and inadequacy becomes part of their personality. Steele has found that students of

highly stigmatized groups underperform in testing environments in which the social stigmas of their group are made salient. This is impactful because it has been shown that students begin to develop stereotype consciousness as early as the age of six (McKwon & Weinstein, 2003). The researchers (2003) suggest that stereotype consciousness is the awareness that others may endorse stereotypes and discovered that students of academically stigmatized groups (African-American, Latinx, and Native American) begin to develop stereotype consciousness between the ages of six to ten. Furthermore, data revealed that students of the stigmatized group were more aware by the age of six of broadly held stereotypes in contrast to those in a non-stigmatized group (White and Asian). This is a probable reflection of the salience of stereotypes in the daily lives of students of color (McKwon & Weinstein, 2003). This could be problematic as students in third grade begin the process of taking standardized state tests at the end of their academic year. Minority students in this grade, whose classroom environment has promoted stereotypical biases, may not perform well compared to their White and Asian counterparts. Individuals only need to be aware of negative stereotypes, not directly impacted, about their group for them to be susceptible (Beasley et al., 2012; Delpit, 2012; Steele, 1997). Couple this experience with the lack of quality in math teachers and instruction found in majority-minority schools, and we see a clearer picture of why students have a challenge of attaining mathematical literacy.

Quality of Mathematics Teachers and Instruction in Urban, Low-Income Schools

Teachers are significant to the learning process of all students because they interact with them daily. If students are not achieving, the pedagogy and practice must not be designed to reach high student achievement (Clotfelter, Ladd, Vigdor, & Wheeler, 2007; Darling-Hammond, 2004; Ladson-Billings, 1997). Current literature suggests that high-poverty schools face the predicament of staffing a large percentage of unqualified or novice teachers. Inexperienced

teachers lack strong math instruction. This impacts the successful mathematical experiences of students of color.

Teacher Quality. British educator Peter Mortimore cited that the quality of teaching has six to ten times as much impact on achievement when issues such as poverty, crime, family issues and so on are combined (Delpit, 2012, p. 73). This is a powerful implication and understanding as it relates to low-income schools, especially since they do not have the privilege of high-quality staffing of educators. High-poverty, K-12 schools have found it extremely difficult to staff quality teachers within math and science classrooms (Bolyard & Mayer-Packenham, 2008). A lack of quality of teachers in many urban, low-income schools creates a disinterest in mathematics with students of color. This is directly related to inexperienced teachers being less likely to teach inquiry-based or problem-based mathematics that is challenging for students of color. More experienced and well-prepared teachers tend to teach in suburban schools while novice and unqualified teachers are found in rural and urban schools (Clotfelter et al., 2007; Smith et al, 2016). One explanation for this gap in quality teachers in low-income schools is the fact that experienced teachers "trade up" in the district, a process of transferring out of their roles in high-poverty schools to open positions in more affluent schools. This internal process thus leads to new teachers taking over the jobs found in schools that have a large percentage of African-American, Latinx, and Free and Reduced Lunch (FRDL) students (Clotfelter et al., 2007). African-American and Latinx students in low-income schools are much more likely to be in a classroom with a novice teacher, or a teacher with weaker qualifications, than their White peers (Goldhaber et al., 2015). Also, teachers from alternative teaching programs are prominently assigned to low-income schools such as the Teach for America program.

The Teach for America program places intelligent, hard-working graduates (with a short period of training) into low-income schools with the commitment to teach for two years. After the teachers have met their obligation, some stay, but the majority leave for other opportunities. These teachers are the least effective in producing growth in student achievement, and that quality increases dramatically during the first three years (Clotfelter et al., 2007; Delpit, 2012). Thus, the constant replacement of experienced teachers with recruits will continue a cycle of providing an unsubstantial education for children in low-income, urban schools (Delpit, 2012). Consequently, for our African-American and Latinx youth, this sends a negative image of unworthiness to be taught as teachers leave. Contributing to this picture is the passive instruction that can be found in such schools.

Math Instruction. Because of the constant focus on performance on standardized test scores, much of the pedagogical practices embraced and used in urban, low-income schools have been reduced to test prep, continuous worksheets, and over-reliance on textbooks and district created pacing guides. Much of the mathematics teaching practices emphasizes repetition, drill, convergent and right-answer thinking (Delpit, 2012; Ladson-Billings, 1997). In low-income schools "pedagogy of poverty" (Stinson, 2006, p. 486) is prevalent. Pedagogy of poverty is the routine of teaching acts, giving information, giving directions, monitoring seatwork, assigning and reviewing assignments, punishing noncompliance and giving grades (Stinson, 2006). This communicates a negative image that the teacher is the ultimate authoritarian and the student is to always be obedient. The repetition of decontextualized learning may work for a while, and help raise test scores, but this instructional methodology fails when students are not engaged. Students of color who attend urban, low-income schools are deserving of good teachers and powerful instruction (Delpit, 2012). Yet, these students are exposed to teachers that are very passive in

their instruction. Students that are in low-income schools lack the resources needed to provide an enriching math classroom (Smith et al., 2016). Even the least sophisticated technology, non-graphing calculators, are approximately 18% less available in classes of mostly low-achieving compared to high achieving students (Smith et al., 2016).

Students of color need instruction that is focused on building critical thinking (Delpit, 2012; Zamudio et al., 2011). Much of this practice is found in upper-level courses, which are not prominent in urban, low-income schools. Schools attended by large numbers of students of color have fewer advanced placement classes (AP) (Zamudio et al., 2011; Byun et al., 2015). Black and Latinx students are more likely to be enrolled in Algebra 1 and Geometry but less likely to have access, or be enrolled, in higher-level mathematics courses (Berry, Ellis, and Hughes, 2014).

Improvement in mathematics teacher quality is possible by adding criteria to teacher credentialing such as understanding the social context, cultural backgrounds, and identities of the students they will serve (Berry et al., 2014). Allowing for a more critical lens as it relates to using the No Child Left behind (NCLB) metric, which informs the definition of what a highly-qualified teacher looks like. Research suggests that mathematics teachers who understand the social and cultural background/identities of their students see this as resources (Berry et al., 2014). These resources are in turn used to help build students problem-solving techniques, understanding of mathematics across contexts, and help students apply and connect math as a tool examining social inequities, which leads to higher motivation in mathematics learning. Mathematics and equity professional development that allows teachers to recognize such opportunities are much needed in schools (Battey & Frank, 2015). Professional development focused intently on changing the narratives that teachers communicate in urban schools about

their African-American and Latinx students' ability positively impacted teacher instruction (Battey & Frank, 2015). Such professional development pushes teachers in moving away from the metanarrative of what their students "can't do" to what they "can do". Providing such support found that teachers began to focus on how to actively support their students, witness growth, and build the mathematical capacity of their students.

How Do African-American and Latinx Students Internalize Such Experiences?

It is evident that African-American and Latinx students in majority-minority schools are predominantly faced with racial factors that stem from the idea of colorblindness, which is detrimental not only to their success in mathematics but their journey towards economic equality as compared to their White and Asian counterparts. Due to these factors, African-American and Latinx students internalize their negative experiences which in turn may affect their self-efficacy and how they identify with the culture of mathematics.

Self-efficacy. Students' beliefs about their math ability and its value play key roles in math achievement and occupational decision-making. A students' perceived efficacy and academic orientations shape the different types of career pursuits, which allows them to be more selective of the careers they choose and the ones they shun (Bandura, Barbornelli, Caprara, & Pastorelli, 2001; Diemer, Marchand, McKeller, & Malanchuck, 2016). Self-efficacy is the belief in one's capability to organize and execute courses of action require to produce a given attainment (Booth, Abercrombie, & Frey, 2016). The level of self-efficacy that a student has in math aids in the decision-making of coursework in K-12 schools. If students have a high self-efficacy in math, the more likely they will pursue advanced mathematics coursework that will lead to more opportunities in high-paying careers. The culture of math in the United States promotes this subject area as one that should be feared, revered, and that the gifted will succeed

(Boaler & Staples, 2018; Ladson-Billings, 1997). Therefore, it creates high anxiety in students that impacts their engagement and achievement (Griggs, Kaufman, Merrit, & Patton, 2013).

We know that student-teacher interactions can play a promotive or corrosive role in motivating students, achievement, and building a students' self-efficacy (Diemer et al., 2016). Interestingly, Bandura et al.'s (2001) study found that student academic achievement played little value in students chosen career paths because students saw academic content lacking relevance. The lack of relevance plus the added factors of the racial climate in schools, the present culture of mathematics, and the lack of African-American and Latinx representation in mathematics could explain why students do not epitomize a mathematical identity.

Identity. The process of identifying with other individuals and one's ethnicity becomes increasingly salient during adolescence into adulthood (Arnett, 2010; Booth et al., 2016). As minority students progress through their K-12 years, they experience difficulty in aligning their identities with their ethnicity and that of the school culture. This challenge, in turn, leads to many underrepresented minorities suffering an identity crisis as they progress in school. Because of this identity crisis, African-American and Latino students find it challenging to identify, or dis-identify, as a mathematician. Academic dis-identification occurs when students devalue the importance of academic performance to protect their perceived selves (Griffen, 2002).

African-Americans, particularly males, often experience both deficiency and rejection in school (Stinson, 2006). For example, educators and administrators suggest that the way that minorities act is wrong (Delpit, 2012). African-American and Latinx students are challenged with either deciding to give up cultural norms in return for academic success. The burden of "Acting White" (Ogbu, 1992) and stereotype threat pushes African-American students to reject or remove school success from their identity. Dis-identification invokes feelings of alienation in

the academic world (Delpit, 2012; Griffen, 2002). Students of color who withdraw from school, dis-identify with the institution, do not define themselves as part of the setting, and greatly value the outside-of-school culture.

Students who believe mathematics is identity congruent will be more likely to persist in math courses (Anderson & Ward, 2013). Identity congruence allows for students to maintain their racial identity and that of a mathematician. Unfortunately, math and science careers may seem foreign to minorities because of the lack of representation in such fields. There is a need to provide instruction in which students can see men and women of color within the areas of math and science. This will allow minority students a glimpse that they too can align their racial identity with that of the culture of mathematics. Therefore, schools should encourage the development of a math identity in students by incorporating culturally responsive teaching into math classes. Culturally responsive education helps to use the cultural norms, funds of knowledge that students possess as a mechanism to promote engaging and effective curriculum amongst African-American and Latinx students. Providing a curriculum that is culturally relevant and equitable allows such an opportunity.

Conceptual Framework of Critical Race Theory, Culturally Relevant Pedagogy and Mathematics

This study combines the tenets of Critical Race Theory (CRT) and culturally relevant pedagogy (CRP) to provide a framework of exploring the mathematics curriculum and instruction for students of color that takes place in many K-12, low-income schools. CRT was birthed in the legal realm prominently during the civil rights movement (Ladson-Billings, 1998). CRT has four components that exist within the legal realm: (1) CRT begins the notion that racism appears normal and natural to people in American culture, (2) it provides an element of

storytelling, (3) it insists on a critique of liberalism, and (4) that Whites have been the primary beneficiaries of civil rights legislation (Ladson-Billings, 1998). In education, CRT looks at our educational system through an analytical lens and makes the inequities apparent that are produced by our school systems. Zamudio et al. (2011) states, "Meritocracy assumes a level playing field where all individuals in society have an equal opportunity to succeed" (pp. 11-12). This common myth is perpetuated through our school system. What CRT brings to the forefront is that meritocracy cannot be a realization as racism is very present within our schools. It exposes that many of our students of color do not experience equal opportunity in education. Equal opportunity is the idea that students of color should have access to the same school opportunities such as curriculum, instruction, funding, and facilities as White students (Ladson-Billings, 1998). Major educational reforms have worked to create access to schools, but have not focused on the quality of education for students of color (Zamudio et al., 2011).

As Critical Race Theory illuminates that racism is still present within schools, Culturally Relevant Pedagogy provides an avenue in which educators can use student's culture and experience as a tool for students to understand the world and empower students to become active citizens (Delpit, 2012). For this study, CRP will be used as a framework to investigate the pedagogical decisions that educators make while educating African-American and Latinx students. CRP is based on three tenets: cultural competence, academic achievement, and sociopolitical consciousness (Ladson-Billings, 1997). Culturally relevant teaching requires teachers to demand and produce academic achievement in students. Teachers must attend to students' needs and have them choose academic excellence. Culturally relevant teachers create classrooms where students learn both about their own and other's cultures and develop pride in their own and other's cultures (Aronson & Laughter, 2016). Lastly, culturally relevant teachers

create a sense of agency in African-American and Latinx students. Thus, creating a belief that students can challenge and change socially unjust situations, and that they can make a difference in the world from youth to adulthood.

While CRP focuses on the importance of cultural capital in mathematics classrooms, it does not create an explicit focus on how race and racism has been a prominent factor within K-12 mathematics classrooms. CRP and CRT help to inform the type of pedagogy that is needed to serve the diverse American classrooms (Brown-Jeffy & Cooper, 2011). Therefore, teachers must construct pedagogical practices that are culturally relevant, racially confirming, and socially meaningful for their students. It should be clear that race has always and continues to matter in an increasingly diverse society (Howard, 2003).

Benefits of Culturally Responsive Pedagogy in Mathematics

K-12 school systems can produce such inequitable mathematics experiences that deter students of color from creating solid mathematical identities. The problem becomes much more salient as many of these inequitable experiences are found in urban, low-income schools in which students of color make-up the majority. The United States federal government promises equal opportunity for all, but equal opportunity is not a prominent aspect of our urban, low-income schools. African-American and Latinx students in low-income schools lack access to opportunity, time, and quality (Tate, 2001) necessary for successful math experiences. Such experiences (coupled with covert acts of racism) attribute to many African-American and Latinx students dis-identification from a mathematics identity.

However, Culturally Relevant Pedagogy could counter these negative experiences and provide an avenue of success for students of color. There is a growing amount of research that has found the use of Culturally Relevant Pedagogy to be successful amongst African-American

and Latinx students in mathematics (Delpit, 2012; Hammond; 2015; Ladson-Billings, 1995a, 1995b, 1997, 2014). The benefits of Culturally Relevant Pedagogy are academic achievement, cultural competence, and sociopolitical consciousness. These benefits were found to have positive impacts on students' dispositions towards mathematics. Thus, a curriculum rich in culturally relevant teaching can diminish the hegemonic curriculum and ideas of Whiteness found in the math classrooms of many urban schools.

Academic Achievement

The first benefit of culturally relevant pedagogy in mathematics is academic achievement. Mathematics in U.S. public schools tends to be viewed as a neutral subject area that is void of culture. However, culture has a profound impact on cognition (Hammond, 2015; Ladson-Billings, 1997). Hammond (2015) posits that culturally responsive teaching supports cognitive development of dependent learners. Such students benefit when teachers build strong, caring, and reciprocal relationships that create a safe environment in which learning can take place (Hammond, 2015; Hubert, 2013; Ladson-Billings, 1995a, 1995b, 1997; Shevalier & McKenzie, 2012). Also, culturally responsive teachers promote achievement as they know that culture guides how students process information, know that engagement and attention drives learning, and couples new information with existing funds of knowledge in order to be learned (Gutstein, Lipman, Hernandez, & de los Reyes, 1997; Hammond, 2015; Luis Moll, Amanti, Neff, & Gonzalez, 1992). Culturally responsive teachers help students to achieve academically by ensuring that their curriculum and instruction is not only culturally rich, but also rigorous.

Culturally based pedagogy allows every student, regardless of their learning preferences, the opportunity to learn mathematics (Malloy & Malloy, 1998). Many African-American and Latinx students come from cultural backgrounds that value a collectivist nature. Because of such

students of color should be exposed to mathematics that is inquiry-based, which places the cognitive load in the hands of the students, the use of communication to understand mathematical concepts, and to understand that mathematics is a social endeavor (Gutstein et al., 1997; Ladson-Billings, 1997; Malloy & Malloy, 1998). Culturally relevant teaching requires teachers to attend to their students' academic needs and have their students "choose" academic excellence (Ladson-Billings, 1995b). Ladson-Billings (1997) describes a culturally relevant math teacher, Margaret Rossi, who taught algebra concepts to her sixth graders. Rossi created problems that stemmed from her students' background and interests and avoided surface connections, such as replacing students' names in problems. Rossi assured her students that they were capable of mastering the problems presented to them; this act of assigning and treating students as competent allows students to be more likely to demonstrate competence. In addition, Rossi acted as a facilitator of her students' mathematical learning by pushing their thinking through questioning. This allowed her students to understand that they are knowledgeable and capable. Rossi's math instruction demonstrates how real education is about extending students' thinking and abilities beyond what they know and utilizing students' prior knowledge as a bridge from what they know to what they do not know (Gutstein et al., 1997; Ladson-Billings, 1997). The heuristics of her practice allowed her students to "choose" academic excellence. Another benefit of culturally relevant mathematics teaching is building students' cultural competence.

Cultural Competence

Ladson-Billings (2014) describes cultural competence as the ability to help students to celebrate and appreciate their own culture as well as gain knowledge and fluency in at least one other culture. In order to develop cultural competence, culturally relevant teaching requires and aids students to maintain their cultural integrity and academic excellence (Ladson-Billings,

1995a, 1995b). Culturally relevant teachers combat against hegemonic narratives and practices present in schools from the understanding that every student brings with them cultural capital. Cultural capital embodies the norms, social practices, ideologies, language and behavior that are a part of a given context (Howard, 2003). CRP integrates students' cultural capital into the mathematics curriculum. This allows teachers to create experiences for their African-American and Latinx students that is culturally relevant, racially affirming, and socially meaningful (Howard, 2003; Stemn, 2010). An example of how cultural capital can be used in mathematics to develop cultural competence is the Algebra Project.

The national Algebra Project, a program developed by Robert Moses to support algebraic learning in students found in the lower quartile of mathematics, base much of its curriculum on students' real-life experiences (Delpit, 2012; Leonard, Brooks, Barnes-Johnson & Berry, 2010). The birth of the Algebra Project stemmed from Moses's question to students, "In what direction and how many steps is Park Street Station from Central Square?" This problem of displacement allowed students to understand the use of symbols to notate the displacement as positive and negative and effectively use the coordinate plane. The cultural relevance provided students with an accessible mathematical situation that relates to their lived experiences of using the train station - a part of their culture (Leonard et al., 2010). Another example of the Algebra Project in the Mississippi Delta finds students learning equivalency by using African-American cultural understanding of "making do" with an equivalent ingredient (Delpit, 2012). Outside of the Algebra Project, research studies have linked mathematics to other cultural practices that benefit African-American and Latinx students such as playing dominoes, combining problem-solving with basketball, using hip-hop as a paradigm, valuing students use of their native or home language as a tool to communicate mathematics, and even analyzing patterns found in drum

rhythms (Gutstein et al., 1997; Ladson-Billings, 2014; Leonard et al., 2010). Not only does CRP develop academic excellence and cultural competence, but it develops students as critical thinkers and build their sociopolitical consciousness.

Sociopolitical Consciousness

To be truly culturally relevant, a teacher must attend to all three tenets of CRP. What has been seen in research studies is the neglect of sociopolitical consciousness as a practice in many classrooms (Ladson-Billings, 2014; Young, 2010). Sociopolitical consciousness is the ability to take learning outside of the classroom to use school knowledge and skills to identify, analyze, and solve real-world problems (Ladson-Billings, 1995a, 1995b, 1997, 2014). One pedagogical shift to help address sociopolitical consciousness in schools that teach majority minority students is the use of math as a tool for social justice.

In addition to developing sociopolitical consciousness, teaching mathematics for social justice empowers marginalized students to change the status quo, promote social and cultural identities, and creates a sense of agency (Gutstein, 2013; Leonard et al., 2010). A sense of agency in African-American and Latinx students creates a belief that they can challenge and change socially unjust situations, and that they can make a difference in the world from youth to adulthood. The use of mathematical power to critically analyze experiences give students of color the opportunity to voice discriminatory practices that may disadvantage them while privileging others (Gutstein, 2013; Zamudio et al., 2011). For example, a class of seventh grade Latinx students participated in a mathematical task simulating the distribution of world wealth by continents. Students found the percent of each continents population in relation to the world's population and then used those percentages to distribute themselves around the classroom. Students then spread the wealth of the world (using bags of cookies) to each continent (Gutstein,

2013). In this example, students were able to see the inequity of the wealth distribution within the world as some continents received more cookies than others. For this pedagogy to take place in the classroom, teachers must do some work within themselves.

Teaching students to be critical thinkers of the world around them requires teachers to take an in-depth look into their own identities (Howard, 2003; Leonard et al., 2010). Also, teachers need to provide instructional congruence with such identity. Instructional congruence is the process by which teachers build epistemological, cultural, and linguistic bridges between either math (and/or science) and students (Barton, 2002). As mentioned previously, African-American and Latinx students make up a large percentage of students found in low tracked classes in math. An important aspect of teaching math through social justice lens opens the gate that has historically kept students of color and low-income students out of advanced mathematics tracks (Gutstein, 2003; Gutstein & Peterson, 2006).

Challenges of Culturally Responsive Pedagogy in Mathematics

Teaching mathematics through a culturally relevant lens can feel like a risk. Many teachers are subjugated to following a prescribed curriculum, having students meet quarterly benchmarks, and having students perform adequately on the end of year performance assessments. This fear of deviating to far away from what is the norm of teaching reduces teachers to create lessons that are more teacher-centered and reduce mathematics to a set of decontextualized facts that lacks critical thought and conceptual understanding. Morrison, Robbins, and Rose's (2008) meta-analysis found that one-third of classroom teachers observed utilized culturally relevant pedagogy to promote academic success, cultural competence, and sociopolitical consciousness in their students. A huge cause of this is that culturally relevant pedagogy has been widely misconceived by scholars and practitioners (Ladson-Billings, 2014;

Young, 2010). Young (2010) posits that the challenges of implementing culturally relevant pedagogy include (a) the need to raise the race consciousness of educators and confront their own implicit biases; (b) address systemic roots of racism in institutional practices and policies; and (c) preparation of preservice and inservice teachers with the knowledge of how to implement such pedagogy.

As teachers begin to implement CRP into mathematics it is important for them to raise their racial consciousness. It is necessary for teachers to develop a deeper understanding of their own racial and cultural identities (Young, 2010). This will allow teachers to understand the implicit biases they may have about or bring into the classroom that impacts the diverse student population that they serve. A high racial consciousness will help decrease the cultural biases and/or instances of promoting racial stereotypes in lessons as an attempt to make cultural connections. We tend to "teach the way we are", but being a culturally relevant teacher is reflective of if "who we are" contributes to the underachievement who are not like us (Young, 2010). In addition, becoming more racially conscious allow teachers to address racism in institutional practices and policies. Much of the curriculum becomes focus on the dominant group and students of color chances of seeing themselves in the mathematics becomes diminished. Also, instructional practices that promote cultural integrity, democratic practices, and/or critical thinking (which is beneficial for children of color) are not implemented, because schools are more focused on covering material that will be tested, which then reinforces reliance on watered-down and scripted curriculum.

For culturally relevant pedagogy to take root in many K-12 school systems, it must begin with teacher education programs and continue through professional development of inservice teachers. Teachers enter the field of education unprepared in knowing how to effectively teach

curriculum to students of diverse ethnicities (Gay, 2002). Thus, we find many multicultural education classes that have been implemented into pre-service teacher programs as an answer to such absence in knowledge. Currently, the elements of multicultural education are those that have been deemed acceptable by the dominant group (Zamudio et al., 2011). Pre-service teaching programs, and continued professional development for inservice teachers, that implement culturally responsive teaching allows for teachers to develop cultural analysis of instructional materials and revise them for adequate representations of cultural diversity (textbooks, instructional materials, and disparaging information of ethnic groups on various forms of media), creating classroom climates that are conducive to learning for ethnically diverse students, cross-cultural communication, and cultural congruity such as developing rich repertoires of multicultural instructional examples to use in teaching ethnically diverse students (Gay, 2002). A promising professional development model that could help provide both pre-service and inservice teachers with a deeper understanding of CRP is the lesson study model.

Lesson Studies

Originating as a primary form of professional development in Japanese elementary schools, lesson studies have spread as a growing practice in North America. A lesson study is a system of collaborative efforts and live instruction that provide growth in teachers' mathematical knowledge, pedagogical knowledge, student mathematical thinking, and collegial coaching (Doig & Groves, 2011; Lewis, Perry, Foster, Hurd & Fisher, 2011; Lewis, Perry & Hurd, 2009; Lewis, Perry, Hurd, & O'Connell, 2006). Much of the time that mathematics teachers in the U.S. spend on planning is that of a siloed experience and is spent on the "what" to teach rather than "how" to teach. The experience in a lesson study moves away from the "what", but spends a large quantity of time on the "how" to teach that promotes and allows for student thinking to be

visible. This happens as the lesson study model allows teachers to focus on a particular student or group of students throughout the lesson in order to notice if the lesson, or what elements of the lesson, was or was not effective in contributing to student learning (Lewis & Hurd, 2011). The lesson study model provides teachers with a community of teachers dedicated to a shared vision of equitable mathematics teaching and offers a support system to try and test practices to improve mathematics teaching and practices. It also provides an opportunity for teachers to engage in cycles of inquiry to improve practice.

The lesson study model allows such teachers with a common focus to meet, plan lessons together known as "research lessons", collect specific data from the lesson, and give teachers the chance to debrief and discuss the lesson. The focus of the research lesson is either on building skills or an in-depth understanding of mathematics which is taught by a lead teacher. The remainder of the lesson study team acts as an observer of the lesson to collect data for the lead teacher. The debrief at the end of the research lesson is where the lesson is discussed at length, data shared, and modifications are made to the lesson (Doig & Groves, 2011). Lewis et al., (2009) states that a lesson study follows four stages: (1) Investigation, (2) Planning, (3) research lesson, and (4) reflection. In the investigation phase, teachers consider students' current characteristics, long term goals for student learning and development, and the content area (mathematical concepts, existing curricula, and mathematical standards). After time has been spent on the investigation, the lesson study team moves into planning. This stage is where the team selects or develops a research lesson. During this phase, teachers also anticipate student thinking and misconceptions that will possibly be seen during the lesson. Once the planning of the research lesson is complete, implementation of the research lesson takes place. The lead teacher implements and the remainder of the team observes and collects data. After the research

lesson is complete, the lesson study team meets to debrief and discuss the data, implications for lesson redesign is proposed to help improve student understanding and thinking. Learning from the cycle is then summarized in writing and the lesson is retaught (Doig & Groves, 2011; Lewis et al., 2009).

In this study, a lesson study model will be utilized as a sustained model of professional development to aid teachers in developing a deeper understanding of culturally relevant pedagogy. The teaching profession is constantly evolving, and teacher professional development is driven by the need to both extend and renew teacher practice, skills, and beliefs (Doig & Groves, 2011). But, much of mathematics teacher development tends to be ineffective as it does not provide teachers the experience of actually observing how certain practices impacts student thinking. Research suggests that the relationship between student outcomes and teacher development is reciprocal as teachers are more apt to adopt practices that promote further successful student learning (Doig & Groves, 2011). The lesson study model allows for teachers to observe what factors of mathematical teaching helps to promote student learning and extend those practices into other classrooms.

Research Questions

This study explored the experiences of three middle school teachers in the High Tech High organization of schools as the teachers engaged in a lesson study model that allowed for them to learn how to create and implement more culturally relevant, cognitively demanding mathematical tasks into their practice. A unique part of this study investigated if such tasks were impacting students' knowledge and engagement. To this end, the following research questions were investigated in this study using a design-based research method:

3. How does the use of lesson studies help teachers to implement effectively Culturally Relevant Pedagogy in their mathematics classroom?
    a. In what ways does the lesson study model help teachers gain a better understanding of culturally relevant pedagogy?
    b. In what ways does the lesson study model support teachers in creating, refining, and analyzing culturally relevant, cognitively demanding mathematical tasks?
    c. In what ways does the lesson study model support teachers in deciding on effective pedagogical moves?
4. What is the impact of using culturally relevant, cognitively demanding mathematical tasks on African-American and Latinx students' mathematical knowledge and engagement?

CHAPTER THREE: METHODOLOGY

Introduction

This study utilized a design-based intervention as an approach to understand how the professional development model of lesson studies can impact three middle school math teachers understanding and self-efficacy in culturally relevant pedagogy. Through the lesson study model, teachers created, analyzed, and reflected on mathematical tasks that are culturally relevant and cognitively demanding (CRCD) to help improve the mathematics performance of African-American and Latinx students. The purpose of utilizing a design-based methodology is to bridge the research of culturally relevant pedagogy to practical applicability in the complex, diverse environment of the K-12 classrooms (Anderson & Shattuck, 2012; Barab & Squire, 2009; Fishman, Penuel, Allen, Cheng, & Sabelli, 2013; The Design-Based Research Collective, 2003). In this chapter, I first discuss the organizational context of the study. Second, I share the structure of the lesson study model, which introduces culturally relevant mathematics teaching and provides heuristics to help teachers identify, create and refine CRCD mathematical tasks and be able to readily use within their own practice. Third, I discuss the participants of the study and the procedures to collect both quantitative and qualitative data. The chapter will close on how data will be collected and analyzed to answer the research questions.

Context of Study

This study will take place within the High Tech High (HTH) organization, specifically focused on middle school participation. This study will focus on middle school participation as, during the middle school years, minority students academic progress begins to decline (Gutman & Midgley, 2000). Research indicates that although African-Americans, who begin with similar test scores as their White peers, begin to fall by two grade levels during middle school (Gutman

& Midgley, 2000; Steele, 1992). Also, by eighth grade 91% of African-American and 87% of Latino students are not proficient in mathematics as measured by the NAEP (Flores, 2007).

High Tech High is a network of sixteen, K-12 schools that are found in north, south, and central San Diego. In 2000, High Tech High began as one high school and slowly expanded into four distinct K-12 villages. There is an elementary, middle, and high school found in the Chula Vista campus, an elementary, middle, and high school found in the San Marcos campus, two elementary schools, two middle schools, and three high schools found in the Point Loma campus, and a newly added elementary, middle, and high school in the Clairemont Mesa area. The Clairemont Mesa campus is slowly opening with the elementary only having grades K -2, middle with 6th grade only, and the high school with 9th and 10th grades.

High Tech High considers itself an equity project. Beginning from the school's inception, its goal was to create a diverse and inclusive learning environment that is composed of students from varying backgrounds and abilities. This means that HTH K-12 schools are diverse and integrated by design. Students are selected through a blind, lottery process based on postal codes to help represent the diversity of the community either racially, by socioeconomic status, abilities, and life experiences that are found around each village. The HTH schools had an approximate student enrollment of 5,246 during the 2016 - 2017 school year (EdData, 2018). Out of the 5,246 students, 29% Caucasian, 51% Hispanic/Latino, 5% African-American/Black, 8% Asian, 1% Native American, 6% two/more races; 44% Free and Reduced Lunch, 10% English Language Learners, and 12% Special Education. Schools in the High Tech High system utilize a project-based learning philosophy grounded in four design principles: Equity, Personalization, Authentic Work, and Collaborative Design. Because of such principles, conducting an iterative, design-based research study falls within HTH's philosophy.

The Lesson Study Model

The High Tech High Graduate School of Education is focused on supporting teaching and learning throughout the High Tech High organization. This is done through content-specific Networked Improvement Communities (NICs) which are girded in improvement science. The Mathematical Agency Improvement Community (MAIC) is a NIC that is focused on teaching and learning in mathematics to help improve the mathematical performance of underserved, marginalized students within a network of 8 participating schools, outside of HTH, in the San Diego Area and 14 schools within HTH. As a part of a two-year initiative the lesson study model has been implemented as a professional development model to help introduce teachers to student-centered practices, such as anticipatory lesson planning that includes a Launch-Explore-Discuss lesson structure, equitable group work practices, and learning how to refine lessons through student work/observations. The lesson study model has been introduced to fourteen out of the sixteen HTH schools. The lesson study model is an iterative system of collaborative learning from live instruction that focuses on: 1). Investigation of the mathematical task/curriculum, 2). Planning of the lesson, 3). Implementing the research lesson, and 4). Reflection on the lesson as well as a second cycle of the same lesson to follow after the reflection (Lewis et al., 2009). The time and the implementation of the lesson studies is determined by the math content team in each school. For this study, two lesson study cycles were held during the Spring 2019 semester.

The lesson study model engages teachers in methods and tools that help to improve teachers' mathematical content knowledge and pedagogical knowledge. This model is an iterative process that will explore how this collaborative professional development model helps to increase teacher practice and self-efficacy with CRP through the creation of CRCD

mathematical tasks and how such tasks impact students' mathematical knowledge and engagement. In the first phase of the lesson study model, teachers participated in a pre-focus group to unearth what the teachers initially understood about CRP, and the teachers were exposed to a culturally relevant, cognitively demanding mathematical task. This allowed teachers to engage with and experience how powerful such tasks can be that they would be more willing to create and implement such tasks in their classrooms. In the second phase, teachers investigated the current curriculum and resources that they are using in their school and began the process of working through the mathematics and anticipating student thinking. This allowed for teachers to understand the core mathematical ideas that are present within the already existing curricula. During this phase, teachers assessed the current mathematical tasks degree of cultural relevance and cognitive demand using a CRCD rubric (Matthew, Jones, & Parker, 2013) and collaboratively modified the mathematical task to one that is more highly culturally relevant. Also, the researcher and lesson study teachers used a launch, explore, discuss lesson structure to plan the intended lesson. The host teacher, who will be implementing the lesson, and the research team generated a teaching goal that was the focus of the data collection. In the third phase, the lead teacher implemented the research lesson in their classroom and the remainder of the lesson study team collected data around the proposed teaching goal. In the final phase, the researcher and the lesson study team used a debrief protocol to share the lead teacher's reflections and the collected data. During the final phase, the lesson was refined and implemented as a second cycle. Also, during this phase teachers completed a critical reflection journal to reflect on the lesson study cycle experience. The hope for the critical reflection journal was to help teachers become aware of their practice and how it is impacting the work they do with their culturally and linguistically diverse students (Howard, 2003).

Participants

Participants for this study were teachers who worked in the High Tech High middle schools during the 2019 spring semester. At the beginning of the study, six teachers were recruited. One of the teachers decided he could not continue because of prior engagements. Also, two out of the five teachers were not able to fully participate through the two complete lesson study cycles because of prior engagements or lack of flexibility to attend the day of implementation of the research lessons. Because of such changes, this study will focus on the engagement/learning/experiences of the three teachers who were able to participate fully through the two lesson study cycles. The recruited teachers came in with a wide-range of understanding of Culturally Relevant Pedagogy. The only requirements for participation was that each teacher was employed full time and was teaching a mathematics class. Race and gender were not a determinant of teacher participation in this study.

The three focus teachers participated in the lesson study model as professional development to learn deeply how to implement Culturally Relevant Pedagogical practices in their classroom by creating, refining, and analyzing CRCD mathematical tasks. As part of this study students of each participating teacher's classroom were included. Students received a consent form from the researcher and agreed through parental consent to participate in the study. Each participating teacher were included in a case study analysis to critically reflect (Howard, 2003) on their teaching of African-American and Latinx students as well as their engagement (lack of engagement) with CRP practices. The study also included pre- and post-tests to measure how students' mathematical knowledge was impacted through the use of CRCD mathematical tasks and on the spot collection of field notes of student engagement during the implemented lesson.

Procedures

The researcher approached middle school directors about their interest in having their mathematics teachers use culturally relevant pedagogy to impact African-American and Latinx students' math performance through a lesson study model. From the interested director(s), the researcher chose the school site(s) that have the highest population of African-American and Latinx students. The director(s) were presented a form of consent to support this research study on their respective school sites. Once director consent was given, consent was obtained from the mathematics teachers to take part in pre- and post-intervention focus groups, interviews, and collection of artifacts throughout the study. The researcher also provided student consent forms to teachers that allowed the use of student artifacts, pre- and post-tests, and observation of students during implemented math lessons.

The research study was introduced to teachers during the school site's content-specific professional development meetings so that teachers will have an opportunity to ask questions and address concerns about the study with the researcher. Teachers who agreed to participate in the study, signed the consent form. The mathematics teachers who agreed to participate in the study formed our lesson study team. Consented teachers participated in a pre-focus group and experienced a CRCD mathematical task. On the last session of the research study, the teachers participated in a post-focus group. The teachers participated in two cycles of the lesson study model that engaged them in learning and experiencing Culturally Relevant Pedagogy through CRCD mathematical tasks, learned how to find core mathematical ideas from their current prescribed math curriculum, and used those core math ideas and created CRCD mathematical tasks that tapped into their students cultural and cognitive competencies through student-centered lesson structures. Documents generated by the teachers, audio/video recording of the lesson

study planning, observation, and debrief cycles, and interviews of the teachers were collected throughout the intervention. Also, teachers were provided consent forms to provide to their respective students. Students that agreed to participate in the study will return consent forms to their teacher which will be given to the researcher. This allowed the researcher to administer a pre- and post-test to students, collect student artifacts, and also the ability to observe students throughout the lesson. I will provide more information about the pre- and post-test and documents that will be collected in the next section.

After the two lesson study cycles, the researcher conducted teacher interviews with the three focus teachers. In-depth interviews provided the experiences and views of the teachers as they participated in the lesson study cycles, and captured how they were making sense of CRP and implementing CRP in their mathematics instruction as well as explore any shifts in teachers beliefs about how African-American and Latinx students perform in mathematics. Interviews were face-to-face and audio recorded. Interviews were scheduled based on the availability of the teachers and took place in a private room. Below, Figure 1 visually depicts how the process of data collection, quantitative and qualitative, for this study.

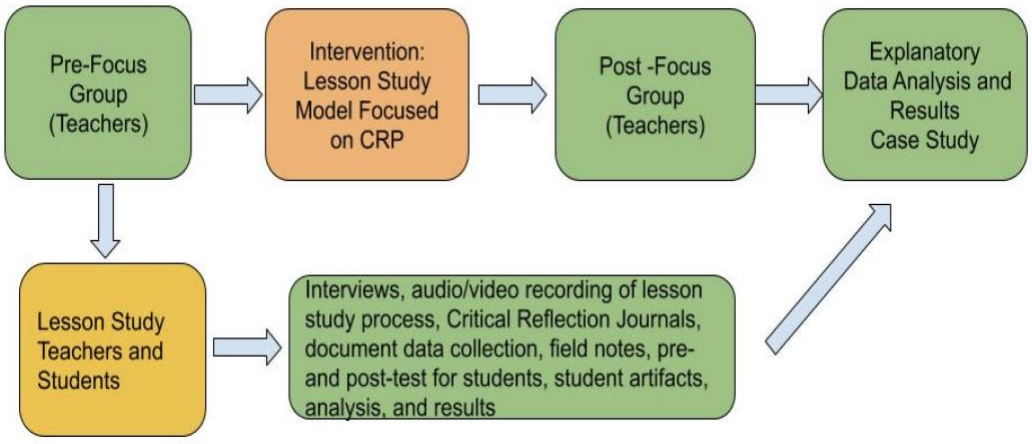

Figure 1. A representation of the Study

Data Collection

Because the lesson study model is an iterative model, each lesson study cycle, in this study, is a case study in itself. Impact and process data were collected throughout the design-based study through quantitative and qualitative methods. The quantitative portion of this study will involve pre- and post-tests for students and field notes tracking students how students were engaging with the CRCD mathematical tasks. The qualitative portion of the study uses case study methodology (Creswell, 2009) informed by critical race theory and culturally relevant pedagogy that examined how teachers were understanding CRP through their participation in the lesson study model and implementation of CRCD mathematical tasks, and how such tasks are impacting their African-American and Latinx students' mathematical knowledge and engagement. The qualitative portion of this study will be collected through teacher interviews, audio/video recording of the lesson study process, documents generated from the lesson study model such as CRCD mathematical tasks, critical reflection journals, observational notes of teacher pedagogical decisions when implementing CRCD math tasks in the classroom. Each data collection source is listed below to describe its use in answering the study's research questions.

Pre- and Post-Focus Groups

Pre- and post-focus groups were administered before and after teachers participated in the lesson study professional development focusing on CRP. The questions on the focus groups were organized around the three tenets of CRP: Academic Achievement, Cultural Competence, and Sociopolitical Consciousness. The focus group questions were adapted and modified from the Preservice Teachers' Culturally Responsive Teaching Self-Efficacy and Outcome Expectancy Beliefs Survey (Siwatu, 2007) and the Culturally Responsive Teacher Preparedness Scale (Hsaio, 2015).

The first domain, Academic Achievement, draws upon instructional and curriculum decisions that teachers make to promote achievement amongst their linguistically and culturally diverse students. The second domain, Cultural Competence, focuses on teachers knowing their students varying cultures and how to infuse such culture into not only the curriculum, but also their classroom environment. Finally, the third domain, draws upon teachers' knowledge of how to connect mathematics to their students' community and the use of mathematics as a tool to analyze local and/or global problems.

Documents

Documents generated by teachers during the lesson study professional development such as created and refined CRCD mathematical tasks and lesson plans, video recordings of each lesson study cycle, and student artifacts from the research lesson. Other forms of documentation include lesson study agendas, protocols, critical reflection journals of teachers after each lesson study cycle, and any additional tools created by the lesson study team throughout each cycle. The documents will support the pre- and post-teacher focus groups by capturing how the teachers are understanding and implementing CRP into their mathematics classrooms, and providing another data source in conjunction with teacher interviews by illuminating teachers' pedagogical knowledge and self-efficacy with CRP.

Interviews with Teachers

In-depth interviewing allows for a deeper understanding of a lived experience and sensemaking that an individual makes of that experience (Seidman, 2011). Also, Seidman (2011) states, "As a method of inquiry, interviewing is most consistent with people's ability to make meaning through language" (p. 14). Parallel to the intervention, qualitative data through semi-structured interviews will be implemented with teachers after the two lesson study cycles. Each

focus teacher will be interviewed to explore their new knowledge or CRP and self-efficacy with the utilization of CRCD mathematical tasks. The interview questions will be based on the scope of where teachers are in the lesson study cycle. Throughout the interviewing process, attention was given to the process of asking for more details and creating a complete picture of each participating teachers' experience throughout this intervention.

Pre- and Post-Test for Students and Classroom Observations

A unique part of this study is to observe if there were any impacts to students' knowledge and engagement through CRCD mathematical tasks. Before each lesson study cycle, the host teacher's classroom of students will be administered a pre-assessment of the mathematical concepts that will take place during the research lesson. The pre-assessment was given to the students before the lesson began. After implementation of the research lesson, during the last 10 minutes of class, students were given a post-assessment. The pre- and post-test provided information on if the CRCD mathematical tasks are providing students with a deeper understanding of the mathematical concepts that will be taught on the research implementation day. Also, classroom observations were conducted to record student engagement with CRCD mathematical tasks.

In each host teacher's classroom, classroom observations were conducted to observe how students were engaging with CRCD mathematical tasks. The classroom observations focused on how students were actively engaging in the task presented. The indicators of engagement that the research team decided upon were: students sharing ideas (creating visuals, starting with an idea or method, explaining their mathematical thinking) by actively engaging with their peers in group discussion, how often students were off-task or participated in off-task conversations, and

how often students are posing and answering questions with each other. On the spot field notes were written during classroom observations.

Data Analysis

In order to answer the following research questions (RQ), the following data was collected and analyzed:

RQ1: How does the use of lesson studies help teachers to effectively implement Culturally Relevant Pedagogy in their mathematics classroom?

To understand the impact of the intervention on teachers' implementation of culturally relevant pedagogy in their mathematics classrooms the pre- and post-focus groups were analyzed (See Appendix A). Open and focus coding (Creswell, 2009; Emerson et al., 2011) was used to analyze the focus group data for themes. Specifically, the focus group data determined if the intervention affected: (1) teachers' curriculum and instruction choices that pushed students to achieve academically, (2) teachers' ability to utilize their students' cultural capital to achieve cultural competence, and (3) teachers' self-efficacy of integrating community, social, and/or political problems in math to promote students' sociopolitical consciousness.

To understand how the lesson study model is helping teachers gain a better understanding of CRP and the implementation of CRCD mathematical tasks, interviews were conducted with each focus teacher and critical reflection journals were done at the end of each cycle. The semi-structured interviews were audio recorded and professionally transcribed. Transcripts were verified by reading through while listening to the recording. Following transcription, the researcher looked for emerging themes through focused and open-coding (Creswell, 2009; Emerson et al., 2011). Documents produced through the lesson study cycle, such as created and refined CRCD mathematical tasks, lesson plans, video recordings of each cycle, and critical

reflection journals, were used to inform how teachers' understanding of CRP was evolving throughout the intervention. Data from the critical reflection journals and video recordings of the lesson study cycles were analyzed for corroborated evidence of the emerging themes and were used to triangulate information to ensure the validity of the findings (Creswell, 2009).

RQ2: What is the impact of using culturally relevant, cognitively demanding mathematical tasks on African-American and Latinx students' mathematical knowledge and engagement?

To address research question, pre- and post-tests were administered to students before and after each lesson study cycle. This helped to inform the researcher if CRCD mathematical tasks impacted students' mathematical knowledge. A paired t-test will be performed on the pre- and post-test to observe an increase or decrease in students' mathematical knowledge after each intervention. Classroom observation data was also collected to inform how students were engaging with the CRCD mathematical tasks. The research team collected data on how often students were sharing ideas, asking questions, and how often students were off-task.

Table 1. Summary of data instruments and analysis.

Instrument	Data Collected	Analysis	Informs
Pre- and Post-Focus Group	Qualitative data related to: • Changes in teacher's use of CRP in mathematics curriculum and instruction to promote student academic achievement. • Changes in Teachers use of students' cultural capital in instruction. • Changes in Teachers use of community, social, and/or political problems to build sociopolitical consciousness	• Open Coding • Thematic Coding	Whether or not shifts occurred in teachers sense of: • Using CRP in mathematics curriculum and instruction to improve student academic achievement. • Teacher using student cultural capital in instruction. • Teachers use of community, social, and/or political problems to build sociopolitical consciousness.
Pre- and Post-test for students' mathematical knowledge (x4)	Mathematical assessment that will be administered before the research lesson and after the research lesson.	• Paired t-test	Increase or decrease in students mathematical knowledge of the concepts and/or skills presented during the research lesson.

Instrument	Data Collected	Analysis	Informs
Semi-structured interviews done after the lesson study cycles (30 mins. each)	Qualitative data after the lesson study cycles tracking: • How teachers are understanding CRP • How teachers experience the lesson study model in helping to create, refine, and analyze CRCD math tasks. • Teacher characteristics that support or hinder engagement in CRP. • School contexts support or barriers with implementation of CRP.	• Open Coding • Thematic Coding	Understanding of the teachers lived experience during the intervention include: • Evolving teacher understanding and/or self-efficacy with CRP. • How teachers use lesson studies to help create, refine, and analyze CRCD math tasks. • Supports and barriers to learning about and implementing CRP.
Classroom Observations	• Field Notes	• Open Coding • Thematic Coding	• Student mathematical engagement with CRCD math tasks.
Lesson Study Documentation	• Professional development agendas • Professional development slides • Lesson study protocols • Critical reflection journals • CRCD mathematical tasks • Lesson plans • Video recording of lesson study cycle • Student artifacts from research lessons	Thematic Coding	Understanding of the teachers lived experience during the intervention include: • Evolving teacher understanding and/or self-efficacy with CRP. • How teachers use lesson studies to help create, refine, and analyze CRCD math tasks. • What pedagogical decisions were teachers making while implementing a CRCD math task. • Supports and barriers to learning about and implementing CRP.

Summary

This research study used a design-based intervention methodology that includes rigorous quantitative and qualitative methods to explore how lesson studies can help teachers to develop a deeper understanding and self-efficacy of CRP in mathematics. The mixed methods intervention study will use pre- and post-focus groups to examine and document any shifts in teachers' understanding of CRP and their implementation of CRCD mathematical tasks in their math classrooms. Interview data from each participating teacher will be coded for emerging themes of how teachers are experiencing CRP to promote student academic achievement, cultural competence, and sociopolitical consciousness. In addition, the interview data will elucidate what facilitation moves impacted teachers' deeper understanding of CRP as well as what other factors support or hinder such development. Survey data, interview data, and documentation analysis will be used to triangulate the validity of emerging themes from each to thoroughly explore the first research question. In regards for research question two, student pre- and post-tests will be

administered to observe any impact of the CRCD mathematical tasks knowledge, and field notes from classroom observations will document student engagement with such tasks.

CHAPTER FOUR: RESULTS

Introduction

This research study used both qualitative and quantitative methods to explore how three middle school math teachers' understanding and self-efficacy in culturally relevant pedagogy (CRP) evolved as they engaged in two cycles of the professional development model known as a lesson study, and how the mathematical tasks created from these cycles impacted students' math knowledge and engagement. The study highlights three focus teachers, who were selected out of the recruited six teachers, as these three individuals participated in every portion of the lesson study cycles. Because of such, the three focus teachers' participation in both lesson study cycles presents influential understanding of how they experienced lesson studies and how this model impacted their understanding and self-efficacy in CRP. Pre- and post-focus groups were used to document shifts in teachers' understanding and practice of CRP as conceptualized as (1) teachers using CRP in mathematics curriculum and instruction to improve student academic achievement, (2) using student cultural capital in instruction, (3) use of culturally relevant, cognitively demanding (CRCD) math tasks to build students' sociopolitical consciousness. Interview data and critical reflection journal responses were used to illuminate themes around how the lesson study model helped teachers to implement CRP in their classroom through curriculum choices and instructional practices. Data from recordings of each lesson study cycle and document analysis were used to triangulate the emerging themes from the focus groups, interviews, and journal responses to thoroughly answer research question one.

This research study also explored the impact of CRCD math tasks on student mathematical knowledge and engagement with the math task. Pre- and post-tests were used to evaluate students' current knowledge on a mathematics concept, chosen by the host lesson study

teacher, and to document any shifts in performance after the implemented research lesson. In addition, field notes from classroom observations were employed to document engagement in the math tasks. In what follows, I share the findings of this research study. I first share the findings from the lesson study cycles. From there I discuss shifts in teachers' understanding of CRP from the results of the pre- and post-focus group interviews, and, lastly, discuss the results of the pre- and post-tests and field note observations of the implemented CRCD math tasks on student performance.

Teacher's Engagement with the Lesson Study Model

This study involved three middle school math teachers' participation in the process of two lesson study cycles. The teachers worked closely together through each stage of the lesson study process: (1) Investigation, (2) Planning, (3) Research Lesson, and (4) Reflection. Analysis of interview transcriptions, classroom field notes, critical journal responses, and documents generated through participation in the lesson study professional development revealed three emerging themes around the subquestions: (1) What about the lesson study model helped teachers gain a better understanding of CRP? (2) What structures of the lesson study model helped teachers to create, refine, and analyze culturally relevant, cognitively demanding math tasks; and (3) How did the lesson study model inform teachers' pedagogical practices that attended to the three tenets of CRP (Table 2). Table 2 lists the themes that emerged from the qualitative data collected from the focus teachers.

Table 2. Emerging Themes from Analysis of Qualitative Data from Focus Teachers

Table 2. Emerging Themes from Analysis of Qualitative Data from Focus Teachers

What About the Lesson Study Model Helped Teachers Better Understand CRP
Theme 1: Collaborative Professional Development Model ● Teacher Collaboration ● Improvement of Mathematical Tasks ● Informal Sharing of Best Practices
What Structures Helped Teachers Create, Refine, and Analyze CRCD Math Tasks
Theme 2: Structures that Support CRCD Math Tasks ● CRCD Math Task Rubric ● Dedicated Time to Collaborate
How did the Lesson Study Model Inform Teachers' Pedagogical Practices
Theme 3: Planning, Observing, and Debriefing Research Lesson ● Prebrief of Lesson Study ● Hosting/Observing Research Lesson ● Debrief after Research Lesson

Table 3 lists the participating lesson study teachers identified by pseudonyms, and their demographic data. The three focus teachers are Alberto, a Guatmalen-Candandian man, Lisa a Mexican-American woman, and Cortez a Mexican-American man. Each teacher was at a different level of experience in their teaching career either as an intern, novice, or veteran teacher respectively.

Table 3. Focus Teacher Demographics

Demographic Category	Alberto	Lisa	Cortez
Gender	M	F	M
Grade Level	7th	8th	8th
Subject	Math/Science	Math/Science	Math/Science
Level of Teaching Experience	Intern	Novice (less than 3 years)	Veteran (more than 3 years)
Years at Current School (as of the beginning of the study)	1	3	10
Ethnicity	Guatemalan-Canadian	Mexican-American	Mexican-American

Theme 1: Lesson Study as a Collaborative Professional Development Model

The lesson study model provides teachers a space to join a community of teachers dedicated to a shared vision of equitable mathematics teaching and offers a support system to try and test strategies to improve mathematics teaching and practices. Aspects of the lesson study model such as teacher collaboration, discussion of mathematical tasks, and informal sharing of best practices allowed teachers to push each other in developing culturally relevant, cognitively demanding math tasks for students, and choosing pedagogical practices to deepen students' learning of the mathematical concepts, which helped to deepen teachers' understanding of CRP.

The first stage of the lesson study model is investigation. During this stage, teachers consider focus students of the lesson(s) (African-American and Latinx students were the focus for this study) and what mathematical tasks and concepts are most beneficial to these students. The focus teachers participated in an onboarding professional development meeting which focused on two goals: (1) introduce teachers to the structure of a lesson study, and (2) provide teachers with an authentic experience of thinking through a CRCD math task. Each focus teacher had previously participated in a lesson study through either the Next Generation Science

Standards Network Improvement Community, the Mathematical Agency Improvement Community, and/or as a part of the math department within the High Tech High Schools. From these experiences, each teacher had some familiarity with the lesson study model. Next, teachers were exposed to the Flint Water Task (Aguirre, Anhalt, Cortez, Turner, & Simic-Mueller, 2019) (Appendix C). This math task provided teachers a model of how a math task can be both culturally relevant and possess high cognitive demand. The task allowed the teachers to create multiple mathematical assumptions, develop multiple strategies, and promoted discussion and justification of each other's mathematical thinking. Not only did the teachers' experience the mathematical discourse promoted through such a task, but they were also exposed to a "real-world" task that required the teachers to inquire about the world around them through mathematics (Matthews et al., 2011). From here, each focus teacher participated in the two lesson study cycles.

Teacher Collaboration

Teacher collaboration is the essence of lesson studies. In a lesson study, novice and veteran teachers come together to support and to help deepen each other's content and pedagogical knowledge. Also, scholars find that novice as well as veteran teachers begin to build a network of collegial relationships and gain the tools for participation in the larger teacher community through their participation in the lesson study professional development model (Lewis et al., 2011). Each focus teacher deeply valued the collaboration that took place during the lesson study cycles.

After the onboarding meeting, the focus teachers and the researcher met to plan the first lesson study cycle. Lisa volunteered to be the host teacher of the first cycle. She provided the team with information about her students, who were majority Latinx students, and the context of

where her students are in their mathematics studies. Her students have been working on their 8th Grade Geometry Unit and would be exploring vertical angles - the angles opposite each other when two lines cross, which creates angles that are always equal - the day of the lesson study. She then shared with the team a 3-Act Math Task, entitled the Railing Problem (Appendix D), that she had considered using with her students. First, the focus teachers collaborated to think about possible student solutions. Then, the team used the CRCD math rubric to assess the initial task's degree of culturally relevance and cognitive demand. Through this deliberation process, the teachers all agreed that the initial task was low in both cultural relevance and cognitive demand, and the team began the process of collaborating to modify the task and plan the lesson (Appendix E). Using the CRCD math task rubric, the team was able to modify the task in which it showed a direct connection to Lisa's students' community and revised the task to be more open, which allowed the students to share multiple strategies and have a richer discussion. When asked what was the most beneficial aspect of this process, Lisa shared, "I think what I most appreciated was hearing others throw out lots of ideas. I'm not creative and brainstorming is not my strong suit, so I like hearing other people's thoughts and seeing what other things you could do." Lisa's reflection highlights how beneficial the collaboration process was for her in preparing a culturally relevant lesson.

After the completion of the first lesson study cycle, the teachers continued to express how important the collaborative process was for them. Lisa continued to share, "I like collaborating and pushing my practice to include things relevant to my students. I was so happy to hear students talking [about] restaurants they know of and engaging in the tasks that way." In addition, the focus teachers saw the importance of co-planning a culturally relevant lesson.

Cortez found that, “I like co-planning a lesson and taking the time to think about it being more culturally relevant.”

Teacher collaboration was noted as an imperative part of the process of learning about culturally relevant pedagogy and creating CRCD math tasks. For the second lesson study cycle, Alberto volunteered as the next host teacher. For his initial idea of a mathematical task, Alberto wanted to continue exploring, with his students, the mathematical concept of percentages through finding the commission of real estate property (a cultural context he believed his students would connect with). Being a host teacher, Alberto found the collaborative process supportive in expanding his thoughts on CRP. Alberto shared:

> [I appreciated] being critiqued by all the different teachers and then seeing their viewpoints were on how I can expand on the cultural relevance of my lesson. I mean I can have an infinite amount of ideas, but like I can’t think of every angle at once. But say I have you [the researcher], now I have two different angles [ideas]. I have Cortez that’s three different angles. I have Lisa that is four different angles. There’s things I won’t think about unless I talk to you [or] talk to somebody else. I would never thought about doing three houses in four different neighborhoods.

Through the collaborative process, Alberto was able to receive multiple ideas of how to expand his lesson to a higher degree of cognitive demand, and created a task that allowed students to think about the differences in commission for the prices of houses that are located in various areas of their community.

Through the completion of the second lesson study cycle, the focus teachers celebrated how collaboration helped them to integrate CRP into math. Cortez claimed that he appreciated “collaborating with colleagues to make math tasks more CRP”. In addition, Lisa valued, “working with a group of individuals that are willing to connect CRP into lessons that would likely otherwise not have it (being math).” The teachers saw that collaboration was essential to their practice of becoming more culturally relevant teachers. In addition, they found

collaboration necessary to help modify mathematical tasks that are culturally relevant for their students.

Improvement of Mathematical Tasks

During each lesson study cycle, the three focus teachers met to plan culturally relevant lessons through the use of CRCD math tasks. Each focus teacher benefits from having autonomy in their classroom, which grants the teachers the ability to choose math tasks that are most appropriate for their students. With this autonomy, each teacher does have to follow the common core standards, and were provided curriculum resources such as the Connected Math Program (CMP) and/or Illustrative Mathematics. The teachers either can choose math tasks from the provided curriculum resources or can find/create their own. For each lesson study cycle, the host teachers were asked to provide the team with a math task they would like to implement as part of the research lesson.

For the first lesson study cycle, Lisa shared the Railing Problem, a 3-Math Act Task, to the lesson study team. A 3-Math Act Task is a lesson structure where the open-ended math problem is broken into three stages of problem solving. Each stage provides more information to students as they move through the problem-solving process. This particular 3-Math Act Task explored the mathematical concept of vertical angles. Act 1 of the initial task asked for students to observe a cross-section of a stair railing and to record their noticings and wonderings. In Act 2, the task highlights for students the angles created by the stair railing, with one angle labeled with an x, and asks the question, “How big is the angle?”. Next, the task moves into a paper-cutting activity that provides a concrete model of how opposite, or vertical angles are equal to each other. Lastly, the task ends in Act 3 with a video sharing the solution for angle, x.

During the planning phase of the lesson study cycle, the team was able to discuss the context and the cognitive demand of the Railing Problem. The focus teachers agreed that the task was not relevant and engaging enough that it would allow students to see the value of the mathematics that they would be exploring. Before the task could be modified/improved, the researcher posed the following questions, *Who are Lisa's students? Where are angles used and seen in the real world?* In addressing the first question, Lisa shared that her students were majority Latinx, most lived in the city of Chula Vista, and that her students enjoyed skateboarding. The team pondered possible real-world contextual ideas that would relate and engage Lisa's students, and created the Skate Path Problem (Figure 2).

The Skate Path Problem

The city of Chula Vista has asked you to create a skate path from the beach to a park. Your team measured angle x during your field work but forgot to measure angle y. How can you determine the measure of angle y?

Figure 2. The Skate Path Problem was modified from the Railing Problem

After the task was modified, Lisa shared with the team that she would like to keep certain components of the Railing Problem such as the "Notice and Wonder" to capture students' prior knowledge and the paper-cutting portion of the task.

Lisa saw a benefit of the collaboration in the lesson study model in improving the math task for her students. In asking her what was the most helpful portion of the lesson study, Lisa shared:

> I think the most helpful was the process of starting with the lesson that was whatever and going through and trying to modify it. So, we started with a problem that already existed and then came up with ways to modify it. And, we saw the before and after. Like, it started here [the initial task] and it went to here [the new task]. It gives you a model to be ok to start with having nothing and here's what you commit to and here's where the lesson itself will actually look.

Lisa's reflection highlights how the collaborative element of the lesson study model was beneficial in creating a problem that was more culturally relevant and cognitively demanding for her students. Also, she highlights how teachers do not have to have a solidified idea of a lesson for the planning stage. In addition, Lisa wants to continue this collaborative practice with her teaching partner. She expressed, "I definitely want to use this problem that we've developed. I think it was really, really, really good. Now that we [her and her teaching partner] have gone through a couple of really big anchor problems, I want to make them more relevant."

Cortez and Alberto saw the collaboration process as an opportunity to talk about their students and having their students represented in the curriculum. Alberto found that the collaboration process of the lesson study model "is pushing me into applying my students' culture into classroom curriculum." Cortez expounds more on the importance of a teacher knowing their students to improve math tasks. He shares, "You have to go put in a little bit [of] extra effort to know your kids and see where you can create a context that's going to engage them and make them feel part of it."

For the second lesson study cycle, Alberto was very enthusiastic about hosting the lesson study. Because of his enthusiasm, he had crafted his own problem that focused on the mathematical concept of percentages. Alberto's initial task focused on finding the percentage of commission sales for a fictional home (Figure 3). Through the collaboration process, the focus teachers were able to help expand Alberto's problem to have more relevance for his students by focusing on multiple homes in areas where his students lived. Alberto found that, "being

critiqued by all the different teachers and then seeing what their viewpoints were on how I can expand on the cultural relevance of my lesson was really helpful." A unique focus of expanding the cultural relevance of Alberto's math task was the sociopolitical component of the problem. The team was able to help Alberto to find actual homes for sale, which had similar square footage, equal amounts of bedrooms and bathrooms, found in various neighborhoods. In addition, the task pushed students to think further about the problem (Figure 4). It initiated thought around the inequity in costs of similar homes in neighborhoods that are heavily populated with people of color compared to areas heavily populated with white individuals.

Home Selling

Juan de la Cruz was able to sell a home in North County to his clients James and his husband for $579,000. If Juan gets 15% commission how much money will he Juan make?
Challenge: **If the house sold for 50% Juan's commission would decrease to 11%. How much money would Juan make it the House sold for 50% more.**

Figure 3. Alberto's original created math task

Home Selling Revised

Juan is trying to find a new home for his clients, James and his husband, David. They are looking to buy a house in one of the four North County communities. Juan wants to find them the perfect home but also wants to make the most commission. His commission percent per community differs as follows:

In which community does Juan have the chance to make the most money for himself? How do you know?

Carlsbad	Vista	Escondido	San Marcos
2%	5%	5%	3%

Figure 4. Alberto's improved math task after team discussion.

The collaborative element of the lesson study model supported the focus teachers in improving the mathematical tasks used for the research lessons. Teachers were able to provide

diverse perspectives to not only improve the cognitive demand of each task, but also the cultural relevance of the tasks. The next step in this collaborative process was for teachers to think about the instructional decisions to use with the improved CRCD math tasks.

Informal Sharing of Best Practices

The improved mathematical tasks alone, however excellent, can be insufficient to improve instruction (Lewis, Perry, Friedkin, & Roth, 2012; Remillard & Bryans, 2004). Although the CRCD math tasks provided an avenue for teachers to engage students in a rich problem-solving experience, such tasks cannot live independently on its own for the purpose of moving students from dependent learners to independent learners. Teachers must have instructional practices and routines that allow their students to carry the cognitive load, and need opportunities to see and try out new instructional practices. The lesson study model promoted growth in teacher instructional practices through collaboration.

Each research lesson followed a planning structure known as Launch, Explore, and Discuss. This structure allowed the teachers to build routines for exploring the CRCD math tasks in a student-centered way. This lesson structure promotes student discourse and highlights student thinking. Each focus teacher attained one or more student-centered practice(s) that was of value to them. Cortez and Lisa both found the strategy of "Notice and Wonder" advantageous to their practice. Lisa shared, "I often begin class with a 'notice and wonder' or 'write everything you can think of about…' to start by connecting to what students know about the topic." Another practice that each teacher found effective was "think-pair-share". The think-pair-share is a routine that promotes discourse with students by providing them time to think about a question, and provides space for students to share their thoughts/questions with a fellow classmate before discussing with the whole class. Cortez highlights the power of this strategy with his students, "It

always gets the conversation going with kids. Kids that are not comfortable with cold-calling, or often more shy to share their ideas, peer sharing always gives them the ok. They think, 'other people have these ideas. Cool, now I'm comfortable to share.'"

Cortez, who did not host a research lesson, was able to take away further concrete practices from the process of collaborative planning and observing the research lessons. He found that his practice was pushed by observing different teacher moves, and felt that learning new teacher moves was one of the most valuable experiences from the lesson study:

> [Observing] different teacher moves, especially this last one. I really loved how you [the researcher] coached Alberto something completely unrelated to the actual CRP problem, but was still just a great coaching method. You shared with him to let kids struggle a little bit. Like, let the kids sit there and have to [restate] someone else's statement and just keep restating until they get it. I think just that type of informal sharing of best practice is the thing that is the most valuable part of collaborating in [these] instances.

Through this small coaching tip, during the implementation of the research lesson in cycle two, Cortez was able to witness a teacher move that he found valuable. Alberto corroborated Cortez's statement, "I, also, put into practice your strategy of restating another student's idea." Alberto felt that this strategy was significant enough that he has begun to implement it into his daily math teaching.

Throughout the planning and implementation phase of the lesson study model, teachers found that teacher collaboration, improvement of math tasks, and informal sharing of best practices impacted their content and pedagogical knowledge as well as expanded their understanding of CRP in mathematics.

Theme 2: Structures that Support CRCD Math Tasks

The three focus teachers reported that two structures were helpful in creating, refining, and analyzing CRCD math tasks: (1) Using the CRCD math task rubric as a guideline and (2) dedicated time to collaborate.

CRCD Mathematics Task Rubric

The CRCD math task rubric served as a tool to guide teachers in selecting/refining math tasks provided to culturally diverse students. The rubric emphasized two main objectives: (1) to provide math tasks that demonstrates procedures with connections to concepts, meaning and understanding of mathematics, culture and community, and (2) doing mathematics for the purpose of becoming empowered intellectually, culturally, politically, and socially (Matthews et. al, 2013; Jones, 2015). The three focus teachers used the CRCD math task rubric during the lesson study cycles to help rate the degree - high, moderate, or low - of the task structure's cultural relevance and cognitive demand.

In both lesson study cycles, the CRCD math task rubric was used as an evaluation of the selected/generated math tasks provided by the host teachers from each lesson study cycle. For lesson study cycle 1, the host teacher, Lisa, presented the initial math task entitled the Railing Problem. The lesson study team (data includes the researcher and one additional teacher), utilized the CRCD math task rubric to assess the level of cognitive demand and cultural relevance of the math task. Table 4 displays the percentage of the teacher's scoring for each description on the rubric for the Railing Problem.

Table 4. Percentage of Teachers Responding High, Moderate, or Low in the Degree of the Task Structure for the Railing Problem

Description	High	Moderate	Low
Mathematics task explicitly requires students to inquire (at time problematically) about themselves, their communities, and the world about them.	0%	20%	80%

Description	High	Moderate	Low
May draw from connections to other subjects and issues.	0%	40%	60%
Mathematics task draws from students' community and cultural knowledge	0%	40%	60%
Task may explicitly seek to add to this knowledge through mathematical activity.	0%	0%	100%
Task is mathematically rich and cognitively demanding, embedded in cultural activity.	0%	80%	20%
Task asks students to engage the discontinuity and divide between school and their own lives - home and school.	0%	0%	100%
Task is real-world focused, requiring students to make sense of the world through mathematics.	0%	100%	0%
The explicit goal of the task is to critique society - that is, make empowered decisions about themselves, communities and world.	0%	0%	100%

The lesson study team reported the task as being low in six out of eight of the descriptions, moderate in two out of eight descriptions, and did not consider the task to possess a high degree in any description. Although, low in many of the descriptions the task did receive a high consensus of moderate degree in the following two descriptions: (1) the task is mathematically rich and cognitively demanding, embedded in cultural activity and (2) the task is real-world focused, requiring students to make sense of the world through mathematics. The teachers appreciated the use of a home's stair railing as a real-world context, and discussed how many students have had experience of living or visiting homes with this feature. However, the team decided to refine the task based on the overall ratings.

During the planning phase of lesson study cycle 2, there was an increase in the ratings per description of the initial math task provided by the host teacher, Alberto. Created by Alberto, the initial math task, Home Selling, sought to explore the math concept of percentages through the "real-world" context of real estate. The data includes scoring from each member of the lesson study team (the three focus teachers, the two additional teachers, and the researcher). Each member of the team individually scored the task's structure based on the rubric. After

individual think time, each member shared their reasonings behind their ratings. The initial task received a majority of moderate ratings as detailed by table 5.

Table 5. Percentage of Teachers Responding High, Moderate, or Low in the Degree of the Task Structure for the Home Selling Problem

Description	High	Moderate	Low
Mathematics task explicitly requires students to inquire (at time problematically) about themselves, their communities, and the world about them.	0%	100%	0%
May draw from connections to other subjects and issues.	0%	50%	50%
Mathematics task draws from students' community and cultural knowledge	0%	100%	0%
Task may explicitly seek to add to this knowledge through mathematical activity.	0%	83%	17%
Task is mathematically rich and cognitively demanding, embedded in cultural activity.	0%	33%	67%
Task asks students to engage the discontinuity and divide between school and their own lives - home and school.	17%	33%	50%
Task is real-world focused, requiring students to make sense of the world through mathematics.	67%	33%	0%
The explicit goal of the task is to critique society - that is, make empowered decisions about themselves, communities and world.	0%	0%	100%

In comparison to the Railing Problem (Table 5), the Home Selling Problem received higher ratings in the moderate degree of task structure and received two high ratings (which was not observed in the railing problem). The increase in moderate ratings could be to Alberto's previous exposure to the creation of a CRCD math task from lesson study cycle 1.

The team found it insightful that the concept of percentages would be explored through real estate. This is illustrated by the consensus in moderate ratings for description one and three (table 5). This appreciation of the real-world context depicted by a 67% high degree rating in the description, *task is real-world focused, requiring students to make sense of the world through mathematics*. Alberto and Cortez agreed that the task, "has a lot of potential, because it's real-world focused and the clients." Not only does the task focus on percentages through

real estate, it included a male couple to highlight the LGBTQ+ (Lesbian, Gay, Bisexual, Trans, Questioning, and More) community. In addition, Lisa found that the task, "is very connected to a real profession and a real process that people go through."

In contrast, the task did receive low ratings in the areas of cognitive demand and how the task promotes sociopolitical consciousness. In regards to the level of cognitive demand, all three focus teachers agreed that the cognitive demand of the task was low. The leading reason was that the task did not offer multiple pathways for students; Lisa shared, "I rated the task low in this area, because I could not think of multiple strategies that students would do." In addition, Alberto stated that his task only allowed, "for students to follow a formula." Although the task presented students a real-world focused task, it did not offer much opportunity for students to use mathematics as a tool for critique. This encouraged the lesson study team to consider how to expand the task to move beyond the mathematics. The team thought the topic of "gentrification" - the displacement of people of color from their occupied neighborhood by the influx of white, middle-class individuals - would allow for students to find the utility of mathematics as a way to expose an inequity. Cortez shared, "The idea of comparing the homes to another neighborhood or zip code would be helpful in tying it into a task that critiques society." The team agreed to refine the task in which students compared multiple homes in the four north county San Diego neighborhoods (two highly occupied by people of color and the other two neighborhoods mostly occupied by white individuals).

The focus teachers found the CRCD math task rubric helpful as a guideline in creating, refining, and analyzing CRCD math tasks, but Lisa appreciated how the rubric helped deepened her understanding of the interconnection between CRP and math. When asked what does CRP and math look like, Lisa responded, "Most of what I know, or what I would say, comes from the

rubric we used. It was extremely helpful to me coming up with the idea of drawing from the knowledge of the community." Lisa highlights how the rubric supported her to become more cognizant of the shared lived experiences from her students and their respective community, and to use this knowledge as cultural referents in mathematics. She also shared how the rubric pushed her teaching practice:

> It helped me to see what I'm not doing. Especially when we looked at my problem and we used the rubric on it. I was like most of my lessons would fail this rubric. The rubric gave me a guideline of what I should be trying to do so it's not this horrible thing [lesson] you know? I would say that this document gave me a way to evaluate, and as a navigation tool [it] has been extremely helpful and has helped me to know what I need to do and what I'm not doing.

Lisa wanted to continue using this tool outside of the lesson study as the CRCD math task rubric allowed her to determine if a math task possessed high cognitive demand, cultural relevance, and allowed students to critique society or their respective communities. Cortez corroborated Lisa's statement of the usefulness of the rubric by sharing, "I think using the lens [CRCD rubric] in redesigning is the biggest thing to have in mind...It helps me think twice about my lessons."

For each of the lesson study teachers the CRCD math task rubric was a useful tool to determine which math tasks would engage and push their students' mathematical understanding.

Dedicated Time to Collaborate

Another valuable structure of the lesson study model, named by the focus teachers, was the dedicated time to collaborate. Unfortunately, many teachers find the teaching profession to be a siloed experience. Although each focus teacher worked in a PBL school setting, each stated the challenges of meeting with other math teachers to plan and collaborate collectively. Cortez shared how challenging it is to collaborate on math tasks because of not having a common prep period (a set time in the day for teachers to prepare for classes without students), "I have to juggle many multiple things ...in my prep, in order to collaborate well that means another person

needs to have the same time [prep]. It also means that they [other math teachers] to be up to date on everything else such as grading, communicating with parents, collaborating with their team or teaching partner, and just dealing with students issues that pop up." Cortez highlights the multiple responsibilities that a teacher has that can interrupt the process of collaborating with other math teachers on a daily basis. Because of the daily challenges in trying to collaborate, the focus teachers found the dedicated time to collaborate necessary in the creation, refining, and analyzing of CRCD math tasks.

Alberto saw the benefit of the dedicated collaboration time in helping to refine the Home Selling math task. He stated that through collaboration, "It [the math task] was critique and changed. It was a good idea that got better." Alberto admitted to his struggles with creating and/or finding math tasks that have a high cognitive demand, but through the process of collaboration he was provided significant ideas to help increase the cognitive demand of his math task. Also, Lisa expressed a similar appreciation with the dedicated collaboration time, "You know it was nice that we all came up with different ways to modify it [the task], and I don't think that is something that you would necessarily have. You know [if] you were on your own." Not only did the focus teachers appreciate the dedicated time to collaborate on CRCD math tasks, but Lisa and Cortez shared that they wished that every "professional development" incorporated collaboration into its model, and looking at math tasks to edit should be an "explicit goal".

An interesting finding that supports the collaboration element in creating, refining, and analyzing CRCD math tasks was that each focus teacher found it challenging to create CRCD math tasks on their own. When asked about their confidence in implementing CRCD math tasks in their own classrooms, outside of the lesson study, the teachers either expressed hesitation or

uncertainty in their own capabilities. Lisa expressed this concern by sharing, “my main hesitation is that I don’t have the knowledge and resources to show students that would reveal the inequities and injustices in society.” Lisa shares that she struggles with the sociopolitical element of the CRCD tasks when creating the tasks on her own. Cortez shares a similar concern, “I don’t know that any of my lessons would fall into the realm of critiquing.” In contrast, Alberto states that he struggles with the cognitive demand of a CRCD task, “I’m struggling with the cognitively demanding aspect of it.” Through the dedicated collaboration time, it appears that all of the teacher’s hesitations or concerns about creating CRCD math tasks tend to decrease as they are able to rely on each other to support them in an area where they feel weak.

Throughout the lesson study model the structures that the focus teachers saw as beneficial in the creation, refining, and analyzing process were the use of the CRCD math task rubric as a guideline and the dedicated time to collaborate. The rubric provided a lens in providing more engaging, relevant, and cognitively demanding math tasks, and the lesson study structure of collaboration helped teachers rely on each other’s strengths in the modification of such tasks.

Theme 3: How Planning, Observing, and Debriefing Research Lessons Supported Teachers’ Pedagogical Moves

A culturally responsive math teacher is a teacher who attends to their students’ academic achievement, develops students’ cultural competence, and supports students’ utilization of mathematics to critique the world around them. The lesson study process allowed the three focus teachers to not only develop curriculum resources to support this endeavor, but it supported the increase in their pedagogical knowledge to attend to these three areas of CRP. In each lesson study cycle, the teachers met for approximately an hour to prebrief/plan the lesson two or three days before implementation of the lesson. Next, the team utilized a full day to implement and

debrief the research lessons. The team was able to observe and debrief four research lessons. Through the process of prebrief, observation, and debriefing the three focus teachers were provided support in their own pedagogical development that attended to the three tenets of CRP.

Prebrief of Research Lesson

The planning phase of a lesson study begins with the prebrief of the lesson. During this phase, the three focus teachers met to discuss the mathematical goal, mathematical task(s), anticipated student solutions, responses, and misconceptions, and co-created the research lesson. All three of the focus teachers discussed how beneficial it was to collaborate together during the prebrief stage to create culturally relevant math lessons. The teachers discussed how the collaboration process allowed them to have an increase in their self-efficacy of CRP (see earlier sections of this chapter on teacher collaboration, improvement of math tasks, and informal sharing of best practices). Each of these aspects supported teachers in creating mathematical tasks that held high cognitive demand attending to students academic achievement, utilized students' community as a resource attending to cultural competence, and began the process of critiquing society which attended to sociopolitical consciousness.

Although Cortez did not host a lesson study cycle, he found the prebrief portion helpful in brainstorming ideas and sharing best practices. Also, he mentions how he appreciated the protocols, used during the prebrief, to support this, "I also love the protocols for focusing energy and thought. I wonder if I could use the protocols within other aspects of my teaching and gauge how it might shift my teaching as a whole."

Hosting/Observing Research Lesson

In addition to the prebrief, each focus teacher felt they were able to take away something valuable to add to their practice through hosting or observing the research lesson. Alberto, who hosted lesson study cycle 2, shared his experience of teaching a research lesson:

> I missed some steps here and there, which is a little nerve-wracking, especially [when] five other teachers are there and I know you all aren't there to judge me. You know you want to impress everybody, right? You want them to be like, 'yea, that's awesome.' But, I think it was good because everybody was supportive in the classroom. And there was this one teacher [the researcher], who broke the rules about not talking to students, but pushed their thinking. That being said, it showed me where I can stop and ask critical questions versus like I need to go through this lesson so I can move on.

Although, the researcher broke protocol during the research lesson, Alberto found the coaching method very valuable in attending to his students' academic achievement through the practice of questioning. Also, mentioned earlier in this chapter, Cortez found this break in the protocol influential to his practice as well. Further, he appreciated the opportunity to observe another math teacher in action, "I liked getting to see another math teacher's style in the classroom."

Lisa felt that hosting a lesson study opened her to wanting to know more about her students to use this knowledge as a cultural referent(s), "It would be helpful to have more knowledge about [my students] to know what are the right questions to ask my kids...and present my kids with a launch of a challenging task where they connect to." Further, Lisa valued the routine of "notice and wonder" as a way to gather students' prior knowledge and build a connection to new knowledge.

Debrief of Research Lesson

The most valuable learning for the focus teachers' pedagogical knowledge was through the debrief of each research lesson. The debrief phase takes place after the implementation of a research lesson and lasted approximately 30 to 45 minutes. After the completion of each

implemented research lesson, this stage of the lesson study model afforded the teachers an opportunity to discuss student work and a chance to make "tweaks" - small changes and/or adjustments - to the lesson and how the lesson was facilitated. From these "tweaks", there was noticeable shifts in how the host teachers' attended to academic achievement and cultural competency (two out of the three tenets of CRP). As for addressing sociopolitical consciousness explicitly, this was a challenge for both host teachers.

Debrief of pedagogical moves. During the debrief session, the lesson study team was able to highlight specific pedagogical moves that the host teachers, Lisa and Alberto, demonstrated as well as provided additional ideas that supported the cognitive development of the students.

During the implementation of research lesson one, Lisa began by having students participate in the routine of "notice and wonder" to engage students in the Skate Path task. This strategy allowed her to gather students' prior knowledge and it promoted discussion with the students. For example, A female, latinx student shared, "The streets Broadway, 4th, and 3rd are parallel." Another student also noted that the skate path intersected with the parallel lines. During the debrief of the lesson, Cortez and Alberto shared that they found the notice and wonder routine provided an opportunity for much of the conversation as students shared a majority of ideas at the tables they were observing. Alberto shared, "A lot of it [sharing ideas] was at the beginning. Oh, I think this and I think that." In addition, Cortez shared, "A lot of the things were were hoping to hear came out at the beginning." This highlights how the pedagogical move of launching with a notice and wonder routine provided an avenue for Lisa to access necessary student prior knowledge in order to couple that understanding with the concept of vertical angles.

Also, from the debrief the team decided that it would be best for the map of Chula Vista to be printed and placed at the tables. They saw this as a benefit as some students communicated that they could not see the map during the notice and wonder. Cortez agreed with this idea by sharing, “I think that’s a really good idea too, because we also didn’t get to return to it in the first conversations.” Cortez expressed, “I think maybe having it printed out, they’ll keep that task in mind.”

Another discussion point in the debrief of research lesson one was the use of the paper folding to help students think through the task. As part of the explore of the lesson, Lisa had her students take a sheet of blank paper and fold it into an X to create two sets of opposite angles. The students were instructed to cut the angles out and work together to come to a consensus on which angles were equal to each other. From there, the students moved into doing an additional paper folding activity, but this time creating three parallel lines and a transversal. The team reflected on this pedagogical move and decided that they found the visual helpful, but took a large amount of instructional time as well as moved students away from the mathematical task. Alberto suggested, “I wonder if, just because folding and cutting that is time. I wonder if it’s also a good idea for them [students] to draw the X on their paper and see where the angles match up. So they always have it.” The team slightly disagreed and felt that the cutting was necessary, Cortez shared, “I think it is necessary. If we had an expert group the first round, you could leave it [for students to explore]. Now the second round, if you want to send that person back for another exploration and bring it back to their table, you can set it up. That would save a lot of time.” In addition, Cortez shared how using the paper folding, being more student focused, could support status - how students perceive their mathematical ability in the classroom - of quieter students being the one to present the hint, “Yea, I think this may allow more quieter kids a little

bit more status and more voice because they won't have a choice." After deliberating, the team found the paper folding visual essential to support students in their thinking of how to find vertical angles and decided to use it as a more student-centered practice.

Because of this slight "tweak" of using the paper folding as a hint for students to use to support their thinking through the math task, student conversations exploded. Students shared how they noticed that the angles were equal and began to think about angle measures. Lisa commented during the second debrief, "I thought the idea of doing just the one [paper folding] and transferring that over worked really well." Lisa also noted that with this tweak, "a lot of groups were like, 'well, if they are parallel they're going to make the same angles.' Which I thought was a good theory." Alberto shared that with this tweak that students were sharing more about parallel lines and were trying to explore the relationships of the angles, "There was a boy at the table, who was already looking at the inner versus outer angles. And I think Maxine [pseudonym] was too." Because of this one tweak, the team noticed there was an increase in how often students shared ideas and asked questions of each other.

The tweaks made from the debrief session allowed for Lisa to attend to her students' academic success with the mathematical concept and utilize their own cultural knowledge as a way to guide their thinking.

Lesson study cycle two, hosted by Alberto, emphasized the power of the lesson debrief on a teacher's pedagogical decision making. Alberto utilized the pedagogical strategy of "notice and wonder" to begin the lesson with his students. He shared during his reflection:

> I think what went well was the independent think time at the beginning with the wondering, what questions they have. Some students got excited and shared, 'This is my neighborhood.' I heard that a few times. And, sometimes I [heard] they say I live in Escondido, I live in Vista, I live in San Marcos. So for the cultural relevance, I thought that was always good.

Cortez and Lisa agreed with the level of engagement of the task. Lisa corroborated this statement, “The kids were super interested in the houses. I think that was a great sign when they first walked in.” The team felt that the cultural context of the task was highly engaging for the students.

As students engaged in the math task, the team noted that the students struggled with the vocabulary word “commission”. Lisa suggested that the word either be defined as a group or by the teacher as it impacted the cognitive load of the group. Cortez also noted that there should be more context on home sales as he saw a difference in who was able to access the task based on race, “I think also, too, it might help to give just a little bit more context on just home sales and how they’re sold and who is involved. I'm racking my brain about how the two white boys and white girl could dive right into the math and not the Hispanic male [at the table].” Cortez saw a disconnect in how students accessed the information based on racial/cultural ties to students understanding of real estate. This was a tweak that Alberto found insightful and readily used in the second implementation of the research lesson.

Further, Alberto asked for advice on classroom management from the team as he felt that this hindered student engagement and thinking at times in the lesson. The team suggested pedagogical moves of “restating” and “think-pair-share” to re-engage students in the task and to keep students accountable. They felt that these two teacher moves could help alleviate some of the classroom management issues that Alberto was perceiving.

Alberto felt that the debrief session was an invaluable experience for him. He shared:

> So, then we had our debrief and I felt that our debrief was great because there was, once again, it was tweaking the minor things. It wasn’t scrapping it. It was tweaking those minor things to make things smoother. Now, it was maybe like five minutes of tweaking. Right. I can take five minutes out of my day to tweak something and it just made it run smoother and built my confidence. Like, ‘Ok, this is not bad at all.’ Like, you know, maybe I can write a problem, do it myself,

> think about it, and do it again now where I have made some changes. It was a pretty legit and effective one-hour math lesson. I got kids to think, I got kids talking!

The debrief session provided an opportunity for Alberto to learn from his colleagues and to not feel judged. He felt supported and excitedly saw that through these "tweaks", or advice, that he was able to push his students to talk about the math. Also, his reflection highlights how much more confident he feels in being able to make adjustments to his lessons in the future.

Through the planning, hosting/observing, and debriefing all three focus teachers (especially the host teachers) felt they had stronger pedagogical knowledge that they could readily apply to their classrooms.

The Impact of Lesson Studies on Teachers' Understanding and Self-Efficacy of CRP

This study began and ended with each teacher participating in a pre- and post-focus group. The intention of the focus group was not only to build trust to share and be critical of their practice, but to allow the researcher to develop an understanding of how the teachers were conceptualizing CRP in their practice. Also, the focus group provided understanding of any shifts in this conceptualization after the lesson study intervention. The focus group interview consisted of questions around how teachers defined CRP, how the teachers made decisions on appropriate instructional materials for students, how the teachers created relationships with students, and how the teachers implemented math lessons that allowed for students to critique the world around them. The results from the pre- and post-focus group do indicate four emerging themes and/or shifts in the teachers' understanding and self-efficacy within the three tenets of CRP: (1) Confidence in Culturally Relevant Pedagogy, (2) Academic Achievement, (3) Cultural Capital, and (4) Sociopolitical Consciousness, as Table 6 illustrates.

Table 6. Emerging Themes from Pre- and Post-Focus Group Data

Theme 1: Confidence in Culturally Relevant Pedagogy
Theme 2: Shift in CRP Tenet 1 - Academic Achievement ● Modifying Mathematical Tasks ● Connecting Prior Knowledge to New Knowledge
Theme 3: Shift in CRP Tenet 2 - Cultural Competency ● Combating Hegemonic Narratives
Theme 4: Shift in CRP Tenet 3 - Sociopolitical Consciousness ● Confidence and Challenge in Creating/Implementing CRCD Tasks

Theme 1: Confidence in Culturally Relevant Pedagogy

The two out of the three focus teachers reported an increased confidence in implementing culturally relevant pedagogy into their respective math pedagogies.

Pre-Focus Group. At the beginning of this research study, the three focus teachers were asked to conceptualize their understanding of CRP into a definition. Two out of the three focus teachers defined CRP as a way to bring all student cultures into the classroom. Alberto defined CRP as a way to bring all student cultures into the classroom. Alberto defined CRP as, "I guess [it's] reading the room and understanding what cultures are in that room, and bring a little bit of everything to the class." Cortez's definition slightly differed from Alberto's as he shared, "I think that, also, means giving students an opportunity to make their learning theirs or take it and apply it to their own culture." Cortez demonstrated a significant understanding of being a culturally responsive teacher as he believed that students should be owners of their learning, and that students should view this learning as valuable outside of the school walls.

In contrast, Lisa defined CRP as, "It's like undoing and recognizing how math and science is already present in communities." Lisa viewed CRP as a process of undoing the

preconceived idea that mathematics is only accessible and present in the dominant culture (white culture). She continues to share how society should view the accessibility of mathematics, “It’s about how can we make these things [math and science] valuable and legitimate in mainstream, and expand what it means to be a mathematician and scientist.”

Post-Focus Group. After the lesson study professional development intervention, two out of the three focus teachers reported an increase in their self-efficacy in CRP and demonstrated a shift in how they defined CRP. First, the teachers each shared their personal self-efficacy in CRP. Cortez shared, “[I feel] a little bit more confident after this round [the second lesson study cycle]. I think using multiple brains and collaborating definitely helps a lot.” The lesson study model presented a collaborative element that helped push Cortez’s self-efficacy with CRP. When Alberto was asked about his confidence in CRP, he revealed, “Out of the gate, when we first started, I wasn’t. I guess I’m confident now [that] it seems more natural to do so given the fact that I’m allowed to. I think that’s like the huge point is that I’m allowed to do it right.” Alberto’s self-efficacy was impacted by the autonomy that the lesson study model presented. He was not restricted to use a textbook or a set curriculum. He was given the freedom to create a mathematical task of his choosing that would support his students of a particular mathematical concept. Lisa shared some contradictory feelings about her self-efficacy with CRP, “I’m probably a no on the ease of confidence. I guess I feel like I have maybe more than the average cultural competency.” She disclosed that, “I don’t want to do it wrong or do it in a way that is not actually beneficial or potentially stereotyping.” Lisa has a fear that she may be overstepping cultural/racial boundaries that could be viewed as stereotypical and would detract from her original vision of “undoing” the prominent image of who is considered a mathematician.

Each focus teacher's definition, or understanding, of CRP shifted after the lesson study intervention. Lisa and Cortez both agreed that they would define CRP similar to the measures on the CRCD rubric. Lisa shared:

> Prior to doing the lesson study, I would have defined it as lessons and classroom environment that incorporated students' own cultures rather than being based in white culture. Now though, my definition is much more specific and draws from the rubric we used to evaluate problems: does the problem draw on students' prior knowledge, does it critique society, etc."

Alberto's understanding of CRP was about including representations of his students, or marginalized communities, into the math tasks, "I define this as creating curriculum that not only shares culture of other students, but also includes outliers in the community. It's not just about their ethnic culture, but, also, gender, religion, sexual orientation, and more." Alberto felt that by adding such members of society into mathematical tasks would create, "a stronger community of educators and learners." This is interesting as this demonstrates that Alberto is aware of all the identities that are present in and out of his classroom and is confident in promoting a new narrative. This attention to the representation of who is included in math tasks, provides an avenue for students to engage in math tasks that allows the teachers to attend to their students' academic achievement.

Theme 2: Shift in CRP Tenet 1 - Academic Achievement

The first tenet of culturally relevant pedagogy is academic achievement in which teachers support their students' learning through intentional curriculum choices and instructional practices. From the intervention, the teachers showed a shift in how they attended to students' academic achievement. Initially, teachers conceptualized this attendance to academic achievement through modifying math tasks.

Pre-Focus Group. During the pre-focus group, an emerging theme of modifying math tasks was used to help understand how teachers were conceptualizing CRP to attend to students' academic achievement. When Alberto was asked to define CRP he shared:

> I would say that Culturally Relevant Pedagogy is work that we provide for the students that is something that they can relate or connect to. [...]I've been changing problems to be about the percentages of Instagram followers. Something that is more relevant to [students], something that is more based on their age, or it can be like their culture too.

Alberto's definition highlights that his understanding of CRP is to begin with the mathematical tasks that he was presenting to his students. He shares an example of modifying the context of existing math tasks to one that he believes that his students will readily relate or connect with based on students' exposure to social media, their age, or areas of cultural knowledge that he has gained from knowing his students' background. This same idea is seen with Cortez as he states, "We [him and his teaching partner] tweaked a lot of the scenarios or context of most of them [math tasks]. More so they are relatable to the age group of our students." The teachers believe that the context of the math task matters to engage students in the process of doing mathematics.

Post-Focus Group. After the post-focus group, there was a shift in how the teachers communicated their understanding of CRP in regards to academic achievement. This new understanding emerged in how the teachers attended to student prior knowledge in order to connect to new knowledge.

The teachers understand that an important component of CRP is building a bridge between what students already know to new learning. Lisa states when deciding on a mathematical task does it "draw on students' prior knowledge?" Lisa and Cortez have both developed pedagogical routines that helps to unearth students' prior knowledge through routines called "notice and wonder", "tell me everything you know…", and "think-pair-share". Lisa

expounds, during the notice and wonder routine that she instructs students to "write everything they [students] can think about to start connecting to what they know about the topic", and Cortez couples this practice with the think-pair-share routine to "help get the conversation going." Alberto gains student prior knowledge by open discussions. He states, "I try to have open discussions about topics and see what students know." The teachers find that there is an importance of student prior knowledge before their students fully participate in a mathematical task.

Theme 3: Shift in Tenet 2 - Cultural Competence

The second tent of CRP is cultural competence. Culturally relevant teachers combat against hegemonic narratives and practices present in schools from the understanding that every student brings with them cultural capital. From the pre- and post-focus group, each of the focus teachers found this as an important element in their understanding of CRP.

Pre-Focus Group. Results from the pre-focus group found that the focus teachers held a strong belief that CRP is about combating against the hegemonic narrative through the exposure of mathematicians/scientists of color. Alberto shared, "I tried to bring in famous biologists who were from Africa, Latin America, who were from Israel, Middle East versus just hearing about Darwin all the time. Letting them hear about other scientists that would look like them or spoke like them." Lisa shared a similar feeling as she expressed:

> You know the show, the Big Bang Theory, is like everything I don't want. Where it's like a bunch of nerdy white dudes that do science and math, and they are saying these things that no one can understand them. You know that's what society views it to mean to be a mathematician and scientist. It's like undoing that and recognizing how math and science is already present in our communities.

Before the intervention, Lisa, Alberto, and Cortez demonstrated that to build students' cultural competence is through the process of representation or through the process of "undoing" the stereotypical image of a mathematician.

Post-Focus Group. Results from the post-focus group highlighted a slight shift in how teachers were developing cultural competency within their students. First, the teachers indicated that building relationships with students supported their cultural competency. Alberto shared that he prefers to "get real with students"; Lisa and Cortez voiced that they take time to do "one on one discussions" or "asks students to share about their weekend and activities outside of school."

All three focus teachers utilized this knowledge in creating or modifying the context of the mathematical tasks they implement. Cortez indicated how this has changed his thought process, "I think about who's in the classroom more than just like any kid, any teeneager, that I would be designing a lesson for. It's got me thinking more about who or who's a person [student] I can focus on. Are they connecting to the lesson?" Alberto and Lisa shared that knowing their students afforded them the opportunity to create "real-world" problems. Cultural competency is the process of building students knowledge capacity of one or more cultures in the classroom, and the teachers shared a common belief that by knowing their students and through the mathematical tasks built this capacity for their students.

Theme 4: Shift in Tenet 3 - Sociopolitical Consciousness

The last tenet of CRP, sociopolitical consciousness, was found to be the most challenging tenet for the focus teachers to demonstrate an increase in confidence.

Pre-Focus Group. When the focus teachers were asked how they create lessons to support students' use of mathematics to understand, critique, or change important equity and/or social justice issues the teachers gave a mixture of responses. Cortez and Alberto both agreed

that they did not feel equipped to do this practice as of yet. Cortez shared, "I can't say that I've ever done that specifically in terms of math." On the contrary, Cortez was able to provide a science example in which students were using what they learned in school to examine the air pollution of an urban environment compared to a suburban one:

> I can think of a class I just went to in Oakland and this teacher was doing a project on clouds in the atmosphere, and the students just had to pick one thing to collect data on. They were going to write a report about it, and these two girls wanted to find the difference in temperatures in suburban vs. urban environments, because they lived in an urban environment and went to school in a suburb. So, they were really proud to take what they're learning and take it back to their homes.

In contrast, Lisa was able to provide an example, within her own practice, where she had students use their mathematical knowledge to critique the world around them. She recalled how her students utilized their statistical knowledge to compare, "trends in positive correlation and negative correlation. One thing that I always try to talk about [with students] is the question do richer people get better grades, get into better colleges, and make more money?" Lisa has her students use mathematics to implicitly think about the opportunity gaps between individuals of higher versus lower socioeconomic status. Also, this topic is very relatable to students as many of them are exposed to images of individuals of higher socioeconomic status through social media. After the lesson study intervention, there is still a mixture of responses in how the teachers attend to their students' sociopolitical consciousness through mathematics.

Post-Focus Group. After the lesson study intervention, results indicate that teachers were now more aware of how to attend to students' sociopolitical consciousness through mathematics, but two out of the three teachers continued to express that they do not feel confident in this area. Although, Lisa shared in the pre-focus group that she had her students use statistical analysis to discuss opportunities gaps between those of differing socioeconomic status, she shared, "Right now, I'd say my lessons are not doing a good job of this. My main hesitation

is that I don't have the knowledge and resources to show students that would reveal the inequities and injustices in society." Lisa demonstrates that she still needs more work on developing her own sociopolitical consciousness as a teacher to create CRCD math tasks for her students to explore. Alberto expressed a similar feeling as he shared, "I have been doing a poor job of this in my teaching career. I do wish to implement more social ideologies in the future with my math lessons."

However, there was a shift with Cortez in this area. Cortez discussed how the CRCD math task rubric helped him to think more about his students and to be cognizant of the type of problems he is presenting to his students. During the post-focus group, he shared that he felt "validated" in the problems that he has being doing with his students that is developing their sociopolitical consciousness. He responded with excitement:

> After the second lesson study, it validated when we were doing taxes. The kids had to think about where you could allocate certain percentages of taxpayer money to different departments of the government...I threw in a figure [an amount] for the border wall, so they can really understand how much a billion is and what part of the pie that is. And, they [students] were like, 'What? That is such a waste of money.' It was a great discussion.

Cortez shared a slice of a project in which students were using the mathematical knowledge to understand taxes and government spending. His response highlights how the lesson study model gave him validation that he was already doing this practice in his classroom.

The three focus teachers experienced structures and supports from the lesson development model that contributed to their growth as culturally responsive teachers in mathematics. As seen with the pre- and post- focus data, it exemplifies how the lesson study intervention did provide the focus teachers with a deeper understanding of culturally relevant pedagogy and provided some shifts in their self-efficacy. The following section details how the use of CRCD math tasks impacted students' mathematical performance.

CRCD Math Tasks Impact on Students' Math Performance

A unique section to this research study investigated if the CRCD math tasks, implemented during the research lessons, impacted students' math performance. Scholars have found that CRP benefits the academic achievement of African-American and Latinx students. Because the classrooms (where the research lessons were implemented) were majority African-American and/or Latinx students, the researcher wanted to examine if CRCD math tasks does in fact impact African-American and Latinx students' math performance. Students were asked to participate in a pre- and post-test to assess their knowledge acquisition of the mathematical concept(s) explored through the four research lessons. In addition, the focus teachers collected field notes to track the engagement of students participating with the CRCD math tasks. As part of this research, the lesson study team defined engagement as students: (1) sharing ideas with one another, (2) asking questions of each other, and (3) on-topic student conversations.

Student Pre- and Post-Test Results

This research study implemented four research lessons that included the CRCD math tasks, the Skate Path problem or the Home-Selling problem. The researcher utilized a Paired Sample t-Test to compare students' performance on the pre and post-tests. Figures 5-6 detail the mean score performance of students who participated in the pre- and post-test during each research lesson from lesson study cycle 1.

Results of Pre- and Post-Test from Lesson Study Cycle 1. For research lesson one, 18 students participated in the pre- and post-test. The pre- and post-test for research lesson one (Appendix F) consisted of three problems in which students were to identify the angle measurement of the missing angle (indicated by a question mark). All 18 student participants, who participated in the pre- and post-test, were Latinx. Figure 5 details that there was an increase in the mean score of the participants after completion of research lesson one. Students mean score on the pre-test of 24.17% increased to a 70.44% post-test. Looking more closely at the data, The Paired t-Test table indicates that the difference in pre- and post-test are statistically significant ($p<.001$) with a large effect size of ($d=-1.12$).

Paired Samples T-Test

Paired Samples T-Test

		Test	Statistic	df	p	Effect Size
math pre-test	- math post-test	Student	-4.731	17	< .001	-1.115
		Wilcoxon	0.000		0.002	-1.000

Note. For the Student t-test, effect size is given by Cohen's *d* ; for the Wilcoxon test, effect size is given by the matched rank biserial correlation.

Assumption Checks

Test of Normality (Shapiro-Wilk)

		W	p
math pre-test	- math post-test	0.827	0.004

Note. Significant results suggest a deviation from normality.

Descriptives

Descriptives

	N	Mean	SD	SE
math pre-test	18	24.167	35.919	8.466
math post-test	18	70.444	37.738	8.895

Figure 5. Student Pre- and Post-Test Results from Research Lesson 1

Research lesson two was implemented after a debrief session, in which changes were made to the lesson. As discussed earlier in this chapter, this research lesson was adjusted to be more student-centered. Figure 6 details the performance of 25 students (21 Latinx, 3 White, 1 African-American), who participated in the pre- and post-test. The pre- and post-test for research lesson two utilized the same questions as the pre- and post-test from research lesson one. Also, figure 6 details an increase in means scores pre- and post. The mean score for the pretest was a

33.32% and increased to a 74.68% post-test. The paired t-test indicates that the difference in pre- and post-test results are statistically significant (p=0.001) with a large effect size (d= -0.72).

Paired Samples T-Test

		t	df	p	Cohen's d
math pre-test 2	- math post-test 2	-3.618	24	0.001	-0.724

Note. Student's t-test.

Assumption Checks

Test of Normality (Shapiro-Wilk)

		W	p
math pre-test 2	- math post-test 2	0.750	< .001

Note. Significant results suggest a deviation from normality.

Descriptives

Descriptives

	N	Mean	SD	SE
math pre-test 2	25	33.320	47.140	9.428
math post-test 2	25	74.680	43.331	8.666

Figure 6. Student Pre- and Post-Test Results from Research Lesson 2

Both research lessons, implemented during lesson study cycle 1, found students to have shown an increase in performance from pre- to post-test. Pre- and post-test results for research lesson two were slightly higher than the results from research lesson one. This could be caused by either students' prior exposure to the mathematical concept of vertical angles and/or the adjustment of the lesson to be more student-centered. However, we do find that the CRCD math task, the skate path problem, did impact students' performance on the post-tests for both research lessons.

Results of Pre- and Post-Test from Lesson Study Cycle 2. For research lesson three, 24 students participated in the pre- and post-test. The pre- and post-test for research lesson three (Appendix G) consisted of two problems in which students were to use their knowledge of

percentages to identify the total amount of commission on a sell. The racial demographics of students, who participated in research lesson three, were 13 Latinx, 10 White, and 1 African-American . Figure 7 details that there was an increase in the mean score of the participants after completion of research lesson three. Students mean score on the pre-test of 21.88% increased to a 60.83% post-test. Looking more closely at the data, The Paired t-Test table indicates that the difference in pre- and post-test are statistically significant ($p<.001$) with a large effect size of ($d= -0.89$).

Paired Samples T-Test

		Test	Statistic	df	p	Effect Size
Math pre-test	- math post-test	Student	-4.361	23	< .001	-0.890
		Wilcoxon	13.000		0.001	-0.848

Note. For the Student t-test, effect size is given by Cohen's *d* ; for the Wilcoxon test, effect size is given by the matched rank biserial correlation.

Assumption Checks

Test of Normality (Shapiro-Wilk)

		W	p
Math pre-test	- math post-test	0.910	0.036

Note. Significant results suggest a deviation from normality.

Descriptives

Descriptives

	N	Mean	SD	SE
Math pre-test	24	21.875	30.674	6.261
math post-test	24	60.833	40.262	8.218

Figure 7. Students' Pre- and Post-Test Results from Research Lesson Three

Research lesson four was implemented after a debrief session, in which changes were made to the lesson. As discussed earlier in this chapter, this research lesson was adjusted to provide a better flow with classroom management and to provide students more opportunities to discuss the mathematics. Figure 8 details the performance of 23 students (12 Latinx, 9 White, 1 African-American, and 1 Asian), who participated in the pre- and post-test. The pre- and post-test for research lesson four utilized the same questions as the pre- and post-test from research lesson three. Also, figure 8 details an increase in means scores pre- and post. The mean score for the pretest was a 19.57% and increased to a 68.48% post-test. The paired t-test indicates that the difference in pre- and post-test results are statistically significant (p=0.001) with a large effect size (d= -1.26).

Paired Samples T-Test

		Test	Statistic	df	p	Effect Size
math pre-test #2	- math pre-test #2_8	Student	-6.048	22	< .001	-1.261
		Wilcoxon	0.000		< .001	-1.000

Note. For the Student t-test, effect size is given by Cohen's *d* ; for the Wilcoxon test, effect size is given by the matched rank biserial correlation.

Assumption Checks

Test of Normality (Shapiro-Wilk)

		W	p
math pre-test #2	- math pre-test #2_8	0.826	0.001

Note. Significant results suggest a deviation from normality.

Descriptives

Descriptives

	N	Mean	SD	SE
math pre-test #2	23	19.565	36.116	7.531
math pre-test #2_8	23	68.478	35.530	7.408

Figure 8. Students' Pre- and Post-Test Results from Research Lesson Four

In Summary, both lesson study cycles saw an increase in students' mean score performance on the post-test as well as each research lesson's post-test being statistically significant. This indicates that the CRCD math tasks do have a positive impact on students' math performance. Also, the results indicate a slightly higher increase in post-test scores for research lessons two and four. Both of these lessons were implemented after the debrief session. This highlights how discussing student work and making "tweaks" to the lesson can impact student performance. The following section will discuss how students engage with the CRCD math tasks.

Student Engagement Results

The lesson study team, which consisted of the researcher, the three focus teachers, and one/two additional teachers, recorded field notes to record the engagement level of students participating in CRCD math tasks. The team decided to assess engagement on three factors: (1) how often students are sharing ideas, (2) how often students are asking questions, and (3) how often students have off-task conversations. To record these particular areas, the lesson study team decided to use a system of tally marks every time students did one of the three factors of engagement. Each person of the lesson study team was placed at a table that included three or four students. The following will discuss the engagement results for each lesson study cycle.

Student Engagement Results Lesson Study Cycle 1. Lesson study cycle 1 consisted of research lessons one and two. Each member of the lesson study team, including the researcher, was placed at a table to observe students and how they were engaging with the CRCD math tasks. Table 7 and Table 8 highlight the findings from research lesson one and two.

Table 7. Field Note Observations of Student Engagement with CRCD Math Task Research Lesson One

Engagement Factors	Observer #1	Observer #2	Observer #3	Total
Sharing Ideas	18	23	19	60
Asking Questions	10	6	5	21
Off-Task Moments	17	3	10	30

Table 8. Field Note Observations of Student Engagement with CRCD Math Task Research Lesson Two

Engagement Factors	Observer #1	Observer #2	Total
Sharing Ideas	55	18	73
Asking Questions	7	8	15
Off-Task Moments	5	7	12

The three focus teachers, including the researcher observed selected table groups during research lesson one. Research lesson two field notes consist of observation from two members of the lesson study team, as one member had to leave after the debrief session because of a prior engagement. During research lesson one, the lesson study found that students shared a total of 60 ideas, asked 21 questions, and exemplified 30 moments of being off-task. In contrast, research lesson two found that there was a slight increase in ideas shared amongst students, but a decrease in the amount of questions asked and students being off-task as 73 ideas shared, 15 questions asked, and 12 moments of off-task conversations. This is an insightful find as the second research lesson saw a shift in how students were actively engaging with the CRCD math task. This shift may have been affected by the adjustments made to the research lesson one during the

debrief stage of the lesson study process. The adjustments allowed the lesson to be more student-centered, which supports students in the creation of their own ideas and relying heavily on their peers to support their thinking through the math task.

Furthermore, there is a similar finding of an increase in ideas shared and decrease in off-task conversations found during lesson study cycle 2.

Student Engagement Results Lesson Study Cycle 2. Lesson study cycle 2 consisted of research lessons three and four. Each member of the lesson study team, including the researcher, was placed at a table to observe students and how they were engaging with the CRCD math tasks. Table 9 and Table 10 highlight the findings from each research lesson.

Table 9. Field Note Observations of Student Engagement with CRCD Math Task Research Lesson Three

Engagement Factors	Observer #1	Observer #2	Observer #3	Observer #4	Total
Sharing Ideas	25	12	8	10	55
Asking Questions	6	6	6	5	23
Off-Task Moments	5	19	4	8	36

Table 10. Field Note Observations of Student Engagement with CRCD Math Task Research Lesson Four

Engagement Factors	Observer #1	Observer #2	Observer #3	Observer #4	Total
Sharing Ideas	14	11	19	14	58
Asking Questions	2	4	7	4	17
Off-Task Moments	7	2	1	0	10

Once again, we find that there is a slight difference in how students engage with the CRCD math tasks depending on the research lesson was before or after the debrief stage of the lesson study cycle. In research lesson three, before the debrief session, students shared a total of 55 ideas, asked 23 questions, and exemplified off-tasks conversations 36 times by the observers. However, in research lesson four students were found to have shared 58 ideas, asked 17 questions, and exemplified 10 moments of off-task conversations. There is a noticeable shift in the amount of ideas shared and a decrease in off-task conversations from research lesson three to four. The results supports that making "tweaks" or changes to a lesson, after looking and discussing student work, can impact student engagement. It is not so much of the math task itself, but the design and facilitation of the lesson that supports students' engagement and how often students carry the cognitive load during a math inquiry.

Summary

These data describe how three math teachers' participation in lesson studies impacted their understanding and self-efficacy of culturally relevant pedagogy, and how African-American and Latinx students' knowledge and engagement were impacted by exploring CRCD math tasks.

Qualitative data from the three focus teachers, including interviews, documents generated during the lesson study cycles, classroom observation data, and participation in a critical reflection journal after each cycle, explored how the teacher's understanding and self-efficacy of CRP changed. From these data three themes emerged: (1) lesson studies as a collaborative professional development model; (2) structures that support creating, refining, and analyzing CRCD math tasks; and (3) planning, observing, and debriefing research lessons. Also, qualitative pre- and post-focus group data indicated shifts in how teachers conceptualized CRP in how (1) teachers used CRP in mathematics curriculum and instruction to improve student academic achievement, (2) used student cultural capital in instruction, and (3) how the use of culturally relevant, cognitively demanding (CRCD) math tasks to build students' sociopolitical consciousness. Analysis of the themes and categories that emerged provided insight into how teachers can better implement culturally relevant pedagogy through their participation in lesson studies.

In addition, quantitative pre- and post-test scores, which were statistically significant, indicated that students' participation with CRCD math tasks did impact their knowledge acquisition of the mathematical concepts. Also, field notes of student engagement with the CRCD math tasks illuminated how students engaged with the CRCD math tasks. An insightful find is that students benefited more from the task/lesson after the debrief stage of the lesson study as student engagement increased in the areas of sharing ideas and decreased in off-task conversations.

CHAPTER FIVE: DISCUSSION

Overview of the Problem

African-American and Latinx students are losing out on the opportunities to take part in high-paying careers and higher education because of a lack of proficiency in mathematics (Beasley & Fischer, 2012). The institutional and individual factors present in K-12 school systems create feelings of alienation and disidentification in African-Americans and Latinx students from math. Failing to provide African-American and Latinx students with a mathematics curriculum and instruction centered on their experiences, culture, and traditions is a deterrent to the achievement of equity in mathematics education. Culturally Relevant Pedagogy (CRP) in mathematics builds on students' cultural capital, prior knowledge, and mental schemas that allow African-American and Latinx students to acquire academic achievement, cultural competence, and sociopolitical awareness. However, math teachers do not have a solid understanding of how to implement CRP into their classrooms. Thus, this design-based intervention study explored how the use of the professional development model known as lesson studies helped teachers to gain a deeper understanding of CRP in mathematics and its impact on student knowledge and engagement.

Overview of the Study

This study explored how three middle school math teachers participation in two lesson study cycles impacted their understanding and self-efficacy of culturally relevant pedagogy, and how culturally relevant, cognitively demanding math tasks impacted student knowledge and engagement. In this study, teachers' understanding and practice of CRP was conceptualized as (1) teachers using CRP in mathematics curriculum and instruction to improve student academic

achievement, (2) using student cultural capital in instruction, and (3) use of culturally relevant, cognitively demanding (CRCD) math tasks to build students' sociopolitical consciousness.

To determine how teachers' understanding and self-efficacy were affected by engaging in the lesson study model, and how students' knowledge and engagement was impacted by exploring CRCD math tasks, the following research questions were posed:

1. How does the use of lesson studies help teachers to implement effectively Culturally Relevant Pedagogy in their mathematics classroom?
    a. In what ways does the lesson study model help teachers gain a better understanding of culturally relevant pedagogy?
    b. In what ways does the lesson study model support teachers in creating, refining, and analyzing culturally relevant, cognitively demanding mathematical tasks?
    c. In what ways does the lesson study model support teachers in deciding on effective pedagogical moves?
2. What is the impact of using culturally relevant, cognitively demanding mathematical tasks on African-American and Latinx students' mathematical knowledge and engagement?

To explore these questions the three focus teachers participated in two lesson study cycles that supported the creation, refining, and analysis of CRCD math tasks that were then implemented in classrooms, which served majority African-American and/or Latinx students, in four separate research lessons. Both qualitative and quantitative data were collected, including pre- and post-focus group data, interview data from all three focus teachers, critical reflection journal entries, pre- and post-tests from students, field notes to track student engagement, and documentation data from each stage of the lesson study cycles. Pre- and post-focus group data, interview data,

and critical reflection journal entries were open coded in an iterative process to uncover significant themes (Creswell, 2009; Emerson et al., 2011). After an initial round of open coding, a second round of coding was completed using the research sub-questions as a lens to group existing codes and identify emerging themes. Student pre- and post-test data was analyzed using the statistical analysis program, JASP, to compare student performance on selected mathematical concepts before and after implementation of research lessons that included CRCD math tasks.

Discussion of Findings

This study yielded important findings on how three middle school math teachers' participation in two lesson study cycles impacted their understanding and self-efficacy of culturally relevant pedagogy. The following will provide a summary and analysis of the focus teachers' experiences in participating in the lesson study cycles, and how CRCD math tasks impacted African-American and Latinx students' knowledge and engagement. In addition, implications for practice, policy, and social justice are described along with suggestions for future research to advance practical applications.

The findings for research question one indicate that the focus teachers benefited from three variables: the collaborative design of the lesson study model, the utilization of the CRCD math task rubric to create/refine math tasks, and sharing of pedagogical knowledge through the cyclical stages of the lesson study model.

Teacher Collaboration. Teachers who utilize Culturally Relevant Pedagogy choose pedagogical moves and curricular material that promotes achievement in African-American and Latinx students. One challenge with implementing CRP into math content stems from the lack of preservice and/or inservice teacher programs that support teachers in the implementation of this practice (Young, 2010). From the qualitative data collected it was clear that the collaborative

model of the lesson studies offered a viable professional development that successfully supported teachers in integrating culturally relevant math teaching into their practice. The structure and design of the lesson study model granted teachers the opportunity to make collaboration the heart of their work, and provided a communal support system for the teachers in providing equitable mathematics experiences to their students. Each focus teacher felt extremely supported by one another, which allowed for trust to develop and a level of vulnerability with each other's practice. This is possible as the lesson study model emphasizes student thinking and the ability to "make various types of knowledge more visible, such as colleagues' ideas about pedagogy" (Lewis et al., 2009). In addition, collaboration on the research lessons afforded a sense of co-ownership of the lesson. This led to a decrease in feelings of judgement for the host teachers and increases in confidence and self-efficacy in improving their practice. Through collaboration, the focus teachers were able to co-create CRCD math tasks that utilized cultural inferrents to provide cognitively rich and meaningful mathematical experiences.

CRCD Math Task Rubric. One structure of the lesson study that greatly impacted the focus teachers' understanding and self-efficacy of CRP was the use of the CRCD math task rubric. The rubric emphasized two main objectives: (1) to provide math tasks that demonstrate procedures with connections to concepts, meaning and understanding of mathematics, culture and community, and (2) doing mathematics for the purpose of becoming empowered intellectually, culturally, politically, and socially (Matthews et al., 2013; Jones, 2015). The focus teachers utilized the rubric to assess initial math tasks considered for implementation with students. The rubric supported teachers in assessing the cognitive demand and rigor of the math task as well as the degree to which the task required students to make sense of the world around them and the use of math as a tool to critique society. The CRCD math task rubric, coupled with

teacher collaboration, provided the teachers a way to combat the hegemonic math curricula that tends to omit the lived experiences and cultural connections that are beneficial for African-American and Latinx students (Aronson & Laughter, 2016; Brown-Jeffrey & Copper, 2011; Delpit, 2012; Zamudio et al., 2011). In addition, the rubric supported the teachers' racial consciousness in creating/refining the math tasks and planning of the research lessons (Young, 2010). The teachers utilization of the rubric allowed them to be more cognizant of modifications of the math tasks that are representative of their African-American and Latinx students, such as wanting to include African-American and/or Latinx characters in the word problems, the communities in which their students habited, and cultural/symbolic representations in the problems. For example, after the conclusion of the research study, Alberto shared that he created a CRCD math task that focused on the symbolic, cultural representations of tattoos. The impact of creating/refining math tasks with the CRCD rubric was amplified by the pedagogical practices that supported facilitation of such mathematical tasks.

Pedagogical Knowledge. The improved mathematical tasks, however excellent, can be insufficient in improving instruction as teachers need to possess instructional routines/practices that supports moving their students from dependent to independent learners (Lewis et al., 2012; Remillard & Bryans, 2004). The lesson study model afforded the focus teachers opportunities to grow in their pedagogical practices in order to serve their African-American and Latinx students' achievement in mathematics. As mentioned previously in Chapter 2, much of mathematics instruction in low-income schools that serve African-American and Latinx students rely upon a banking methodology and convergent thinking (Delpit, 2012; Ladson-Billings, 1997; Stinson, 2006). African-American and Latinx students need opportunities to socialize and grapple with the curriculum (Ladson-Billings, 1997). The first pedagogical move emphasized through the

lesson study model was the use of the Launch, Explore, and Discuss lesson structure. This lesson structure provided an avenue for the focus teachers to access their students' prior knowledge, highlighted their problem-solving and critical thinking skills, and granted students opportunities to discuss each other's mathematical thinking. Through this lesson structure, teachers employed strategies such as "notice and wonder" and "think-pair-share". These particular strategies allowed the teachers to create connections between the math content and their students' existing mental schemas, prior knowledge, and cultural perspectives (Irvine, 2003). Through the implementation stage of the lesson study cycle, teachers were able to observe pedagogical moves from each other that they highlighted as valuable, such as the pedagogical strategy of "restating" - in which students' actively restate each other's thinking to emphasize understanding and promote discourse - which held students accountable for their learning. The debrief stage of the lesson study model was where the focus teachers found the most significance in the improvement of their instructional practice. During the debrief stage, teachers were able to reflect on the lesson holistically and discuss student work. From the debrief, the teachers were able to make "tweaks" to the lesson or adjust/try new pedagogical moves that led to improvement in student performance. At the conclusion of the study, all three focus teachers indicated that they were able to utilize these pedagogical moves into their daily math teaching.

A unique section to this study was the investigation of the impact of the CRCD math tasks, created through the lesson study model, on student knowledge and engagement. Research question 2) What is the impact of using culturally relevant, cognitively demanding mathematical tasks on African-American and Latinx students' mathematical knowledge and engagement?, indicates that CRCD math tasks, coupled with effective choice in pedagogical strategies, did impact students' knowledge and engagement. The study was conducted in classes that served a

majority African-American and/or Latinx student population. Each of the host teachers provided their respective students with pre- and post-math assessments on the specific math concept being explored through the research lesson, which included the created CRCD math tasks. The results from the pre- and post-test for all four research lessons indicated statistical significance in student growth in knowledge attainment after their exposure to the CRCD math task. Each research lesson, the mean score of students' performance increased between 30 to 50% from pre-assessment to post-assessment. In addition, student engagement was shown to improve through the use of CRCD math tasks. The data revealed that during research lessons one and three that student engagement was the most prominent during the launch of the mathematical task, and when students were allowed to discuss their own prior knowledge or cultural connections with the context of the task. This supports Tate's (1995) research that African-American and Latinx students benefit from a mathematics curriculum and instruction that centers on their experiences, cultures, and traditions. However, an insightful find is that student engagement in the results indicate that after debrief stage of research lessons one and three that student engagement in sharing of ideas increased and student off-task conversations decreased during research lessons two and four. This was possible as the host teachers were provided an opportunity to share their reflections on the lesson and provided the team with one or two questions of support in their practice; also, the team was able to view and discuss student work performance and collaborate on ideas to further support student thinking. This highlighted how teacher reflection, teacher to teacher collaboration, and unpacking student work can improve teacher pedagogical and content knowledge that then directly impacts student performance (Lewis et al., 2009). This is a significant indicator of including lesson studies as a professional development model in K-12 schools.

Implications for Lesson Study as a Professional Development Model to Support Teachers' Understanding and Self-Efficacy of Culturally Relevant Pedagogy

Lesson Studies offer a pathway for culturally relevant pedagogy to take root in many K-12 school systems. Novice and veteran teachers benefit from such a professional development model in effectively employing CRP with mathematics to serve students of diverse ethnicities. Findings from this study detail teacher experiences with the lesson study model and provided insight to what structures of the lesson study model impacted their understanding and self-efficacy of CRP in mathematics as well as potential challenges with the lesson study model.

Structures that supported the teachers' participation in the lesson study model included protocols, math PD focused on explicit goals, autonomy in curricular choices, inclusive classrooms, and collaboration with colleagues who share a similar vision of equitable mathematics. Challenges that teachers come across that can hinder their participation in the lesson study model included not having a set curriculum/textbook, not having a common prep with other math teachers, and lack of diversity in the staff.

Supporting Lesson Studies in Impacting Teacher Competency of CRP

Lesson study enables teachers to strengthen professional community, and to build norms and tools needed for instructional improvement (Lewis et al., 2009). These findings are evidence that lesson studies do promote teacher growth in content and pedagogical knowledge. Also, it supports the practice of teachers in becoming culturally responsive math educators, whom attend to their African-American and Latinx students success through conscious curriculum choices that is representative of their African-American and Latinx students and thoughtful implementation of instructional structures/routines that promote problem-solving and critical thinking in their students. As a result of the lesson study model, all three teachers demonstrated shifts in how they

attend to the three tenets of CRP: academic achievement, cultural competence, and sociopolitical consciousness.

In this study it is important to consider the affordances of the pre-existing school structures that allowed the focus teachers to participate in the lesson study model and implement CRCD math tasks into their classrooms, and how these affordances might be different or similar to other educational contexts. Evidence from the post-focus group and interview data indicated that teachers were able to develop a higher sense of self-efficacy in CRP because of the teacher autonomy that they possess at High Tech High. Teacher autonomy permits the freedom to choose goals, teaching methods, and educational strategies that are concordant with a teacher's personal educational beliefs and values (Skaalvia & Skaalvia, 2014). Teacher autonomy postulated the focus teachers the opportunity to choose/create mathematical tasks that served their students' mathematical development. Also, the teachers' freedom in choice meant that they were not pressured to follow a set textbook or curriculum in their daily math instruction. The freedom in curriculum and instructional choices allowed the teachers to focus on modifying the math tasks to be engaging and socially stimulating for students, and provided opportunities for teachers to iterate on instructional practices that best supported student thinking. In addition, inclusive classrooms were seen as essential in the teachers' thinking about the level of cognitive difficulty and cultural representation present in the mathematical tasks. Each focus teachers' classroom included students from various racial/ethnic backgrounds, socioeconomic status, various languages, and learning abilities that's inclusive of students who are classified as English Language Learners (ELL) and IEP/504 students. Because each teacher possessed an inclusive classroom, each indicated that it made them more cognizant of who they were serving when collaborating on research lessons.

Additional structures that supported teacher participation in lesson studies included protocols, having a professional development focused on explicit goals, and collaborating with peers who have a similar vision of mathematics teaching. The protocols provided an equitable structure that ensured that all voices were heard throughout the process of each stage of the lesson study model and focused conversations on student thinking. In addition, the protocols supported the teachers' sense of co-ownership of the math tasks and research lessons. A professional development focused on an explicit goal supported the focus teachers' understanding and self-efficacy of CRP. The explicit focus on improving mathematical tasks for African-American and Latinx students allowed for growth in teachers' awareness of the quality of curriculum and instructional practices that are and have been exposed to these students, and even raised the teachers' own sense of racial consciousness. The collaborative model with teachers, who shared that same vision, allowed for trust and vulnerability to take place as the teachers were open to exposing their own practices in order to improve.

Challenges in Engaging with the Lesson Study Model

This study took place within High Tech High Middle Schools. High Tech High's PBL philosophy demonstrates that collaboration is necessary for high-quality PBL experiences to take place in the classroom from the structure of teaching teams (a partnership between a Humanities and Math/Science Teacher) to networking with outside professional communities. But with this emphasis on collaboration through project creation, there is a lack of dedicated time to collaborate with similar content teachers. As teacher collaboration is the essence of lesson studies, and the findings from this study indicate that teacher collaboration contributed to teachers' self-efficacy in CRP, not having a dedicated time and place to meet and plan can contribute to the inefficiency of the lesson study model. From this study, factors that pose as

challenges for the teachers to engage with the lesson study model in this particular school context included the absence of a common prep period between content teachers, unwillingness to change schedules, and the lack of diversity in staff.

Teaching is an intense, complex, and time-consuming profession. For teachers, this can undermine the opportunities to collaborate with other colleagues. This is especially prevalent when teachers do not have a dedicated time to collaborate with their content-specific peers. A common of teachers is the perception of insufficient time to collaborate and debrief during a busy day (Chassels & Melville, 2009). A structure, within the schools, that each focus teacher stated as a challenge for their lesson study work is not having a common prep period with other math teachers. The lack of a common prep period forces teachers to find time during their work day, usually before or after school, to collaborate. This posed other challenges as some educators may have other obligations before and after school that does not allow them to meet with their colleagues. This was evident in this study. For example, this study began with six teachers, but because of other obligations and time restrictions three of the six teachers were not able to fully participate in each lesson study cycle.

In addition to the time challenge, is the unwillingness of teachers to adjust schedules to take part in certain stages of the lesson study model. Because of certain administrative structures placed in the schools created a challenge for teachers to find the time to be part of the observation of research lessons and the debrief. Stevenson and Nerison-Low (2002) posit that this may be from the persistent individualistic culture present in North American teaching. This was found evident in the study as a few of the teachers were inconsistent in their participation of the lesson study cycles, either being present for the planning stage but absent for the implementation of the research lesson phase.

Another challenge vocalized by the focus teachers was the lack of diversity in the teaching staff. The lack of diversity in the teaching staff creates a deficit in racial/cultural perspectives in teaching students of color (Gay, 2002; Zamudio et al., 2011). A diverse group of teachers may serve as role models, can contribute to culturally responsive curriculum, offer counterstories and help students negotiate their experiences with racism and be advocates on behalf of their students of color (Zamudio et al., 2011). Also, a diverse teaching staff can lead to more conversations around gender, race, or other equity issues that can deepen teachers' and students' racial consciousness and develop their sociopolitical consciousness.

Educators interested in adopting lesson studies as a common professional development practice at their school site may wish to provide a common planning time between content-specific teachers, using a curriculum that does provide a sequence and possible math tasks that can be modified to CRCD tasks, and recruiting math teachers of diverse backgrounds to provide varied perspectives that could help in combating hegemonic curriculum presented to African-American and Latinx students. Also, supportive administrators adds to successful implementation of lesson studies as these individuals can provide support/access/time for their educators to participate in this professional development.

Limitations of the Study

The limitations of this study included the small sample size of three teachers (the study began with six teachers, but three were able to participate in all stages of both lesson study cycles), the single school site, and only conducting two lesson study cycles within a three month time frame. Although the intervention has provided an insightful impact of the participating teachers on their understanding and self-efficacy with CRP, the small sample size cannot be generalized to other teachers who work in other contexts. The qualitative data captured from

each of the teachers will be limited by the fact that all the teachers share a similar school environment and culture. In addition, the limited duration of the study does not provide generalizations of long-term effects on teachers understanding and self-efficacy of CRP, but does provide possible implications that could provide more practicality of how to implement CRP in mathematics.

Additional limitations include the researcher's position as the facilitator of the lesson study cycles with the participating teachers. As such, there is a risk of bias towards the intervention. The triangulation of multiple data sources was employed to mitigate this risk.

Implications for Future Research

This study explored how three middle school math teachers engaged in two lesson study cycles and its impact on (1) teachers using CRP in mathematics curriculum and instruction to improve student academic achievement, (2) using student cultural capital in instruction, and (3) use of culturally relevant, cognitively demanding (CRCD) math tasks to build students' sociopolitical consciousness. Findings suggest that by participating in the professional development, teachers demonstrated an increase in their understanding of how to implement CRP in mathematics and felt an increase in their self-efficacy in utilizing CRP as a driving force in increasing their African-American and Latinx students' achievement in math as well as supporting their students' identities as mathematicians. Teachers valued the collaborative model of lesson studies. Teachers also valued the CRCD math task rubric in supporting the modification of math tasks that better represented and engaged their students. Ultimately, teachers felt that lesson studies were impactful in their journey of becoming culturally responsive math educators.

Due to the small sample size of this study, the length of the study, and the singular school site further research is needed to determine if these effects could be replicated in other school settings and which support structures were most effective. The creation of multiple lesson study teams across various school sites, could provide more in-depth knowledge of how lesson studies do impact math teachers' understanding and self-efficacy of CRP.

Additional research that includes multiple lesson study teams, over an extended period of time, would provide insight into what particular structures of the lesson study model supported or hindered teachers in their self-efficacy of CRP. In this study, the focus teachers all did not comment on how the protocols, or the anticipatory lesson planning document, was helpful or challenging to them. The protocol that was influential to teacher's competency in CRP was the CRCD math task rubric. Multiple lesson study teams would allow for the researcher to understand more of how this rubric supported teachers and a deeper knowledge to what aspects of the rubric was significant. Also, a compelling component of studying multiple lesson study teams would be the development of trust and vulnerability within the teams and how that could impact the teacher's competency and comfortability of undertaking a new pedagogical strategy into their practice, and how this practice transfers over from their participation in lesson studies to their own classrooms needs to be studied more closely.

Another area for future research would be to explore in-depth the student experience with CRCD math tasks. Further research on the mathematical experiences of students would postulate and add to existing research of how beneficial culturally relevant pedagogy is on African-American and Latinx students' self-efficacy and identity in mathematics. Also, there is a need for research on how culturally relevant pedagogy may alleviate experiences of internalized racism for students.

Conclusion

African-American and Latinx students are not pursuing or persisting in economically-advantageous careers, such as STEM, because of the considerable amount of mathematical literacy needed for such careers. African-American and Latinx students lack of proficiency in mathematics is due to the opportunity gaps that are present in many K-12 public schools (Delpit, 2012; Ladson-Billings 1997). Teachers who attend to the academic success of their African-American and Latinx students in the field of mathematics support a promising future for many of these students. Culturally relevant pedagogy provides African-American and Latinx students an equitable mathematics experience that is representative of them and the ability to use mathematics as a tool to critique the world around them. Unfortunately, many novice and veteran teachers do not have adequate understanding of how to implement culturally relevant pedagogy into their math instruction. Lesson study was utilized as a professional development to support math teacher's understanding and self-efficacy in culturally responsive mathematics education.

This mixed methods intervention study found that lesson studies did support teachers' in their self-efficacy of culturally relevant pedagogy. The results of the study found that teachers benefited from the collaborative model of lesson studies, the culturally relevant, cognitively demanding math task rubric, and informal sharing of best practices in becoming more confident as culturally responsive math educators. The outcome of this study supports the benefits of lesson studies being a vehicle of professional development in K-12 schools to improve the quality of mathematics being served to African-American and Latinx students. Also, the results of this study adds to the existing research on the benefits of culturally relevant pedagogy for African-American and Latinx students as students' knowledge of mathematical concepts increased and students experienced high engagement with CRCD math tasks.

APPENDIX A: PRE- AND POST-FOCUS GROUPS

Pre-Focus Group Session

Research: "Bringing the Culture to Mathematics: The Impact of Lesson Studies on Math Teachers' Understanding and Self-Efficacy in Culturally Relevant Pedagogy"

Researcher: Curtis A. Taylor

Welcome

Good morning/afternoon! Welcome to our first professional development meeting for us to explore culturally relevant mathematics teaching. Once again, my name is Curtis Taylor and I am the primary researcher for this project. Also, I am a current 6th-grade math/science teacher in the High Tech High organization.

The results from this study will help me, as well as yourselves, to gain a deeper understanding of what culturally relevant pedagogy is and build our self-efficacy in its use in the math classroom.

Protocol

- No right or wrong answers, only differing points of view
- We're tape recording, one person speaking at a time
- We're on a first name basis
- You don't need to agree with others, but you must listen respectfully as others share their views.
- My role as moderator will be to guide the discussion
- Talk to each other

Focus Group Questions

- How do you define culturally relevant pedagogy?
- Being a teacher we have so many options for instructional materials When you are planning your instruction, how do you decide on what tasks and/or instructional activity is appropriate for your students?
- How do you make connections between new concepts that students' are learning and their prior experiences?

APPENDIX B: INTERVIEW QUESTIONS

Exploring How Math Teachers Deepen Their Understanding and Build Their Self-Efficacy in Culturally Relevant Pedagogy Through Lesson Studies

Date	
Time of Interview	
Place	
Interviewer	
Participant	
Title	
School	

Thank you for agreeing to participate in this interview. The purpose of this study is to explore the experiences grades 6 - 8 teachers as they engage in a lesson study model that will allow for them to learn how to create and implement more culturally relevant, cognitively demanding math tasks into their practice.

Your interview data will be kept confidential. Only the researcher and a professional transcriptionist will listen to and transcribe the information you provide. The audiotapes will be destroyed following the final analysis; no later than August 2019.

Your participation is entirely voluntary and may be withdrawn at any time. If the length of the interview becomes inconvenient, you may stop at any time. There are no consequences if you decide not to participate.

Semi-structured Interview Questions
Questions such as these will be asked after each lesson study cycle with participating teachers.

How are teachers supported/hindered in using Culturally Relevant Pedagogy?

1. How confident do you feel in using Culturally Relevant Pedagogy?
2. Can you describe what Culturally Relevant Pedagogy and math look like to you?
3. What structures or school systems are helpful for you in implementing Culturally Relevant Pedagogy?
4. What structures or school systems are difficult for you in implementing Culturally Relevant Pedagogy?

How do teachers engage in the lesson study model?

5. How has the lesson study model pushed your thinking and practice as a math teacher?
6. Can you describe a time in which you used an idea, strategy, or structure learned from the lesson study into your own practice?

7. What about the lesson study do you find the most helpful in learning about Culturally Relevant Pedagogy? Why?
8. What about the lesson study do you find difficult in learning about Culturally Relevant Pedagogy? Why?

How are teachers utilizing CRCD math tasks?

9. How has the process been for you in creating culturally relevant, cognitively demanding math tasks in the lesson study model?
10. How confident do you feel in creating and using CRCD math tasks in your classroom?
11. Have you implemented a CRCD math task in your classroom? How was that process for you?
12. What structures or school systems help you to implement CRCD math tasks in your class?
13. What structures or school systems make it difficult for you to implement CRCD math tasks?

APPENDIX C: FLINT WATER TASK

ADOPTED FROM JEAN AGUILARE-VALDEZ

Walmart, Coca Cola, Nestle, PepsiCo said that they will donate bottles of water for school children in Flint, Michigan, to help with the city's public health crisis over lead contaminated water. On January 26 the companies said they they are planning to "collectively donate water to meet the daily needs of over 10,000 school children for the balance of the calendar year." To do so, the companies will send 176 truckloads of bottled water - up to 6.5 million bottles - to Flint.

Is the companies' plan a good one? How do you know?

Text Highlighted in yellow

APPENDIX D: RAILING PROBLEM TASK/ANTICIPATORY WORK

Anticipatory Math Planning

1. **IDENTIFY THE TASK - Tap into teen minds (https://tapintoteenminds.com/3act-math/railing-reconstruction/) (Leandra's Task)**
2. Use the Cognitive Difficulty Guide to determine if your task is cognitively demanding enough to sustain discussion. If needed, consider ways to open up the task to increase access and challenge.

3. **IDENTIFY LESSON GOAL:** *What mathematical understanding and/or practices are the goal(s) for the lesson?*

Mathematical goal: Introduce students to multiple theroem regarding parrallel lines and transversals (e.g., corresponding angles, alternate interior) Classroom culture goal: Restating ideas and asking questions

4. **DO THE MATH ON A SEPERATE SHEET OF PAPER:**
What strategies might students use to solve the problem? What is the same or different about the strategies?

Strategy A Students know that a straight line is 180; break into quarters that are 90 degrees each; take the 41 degrees and find the missing side as 139 degrees.	Strategy B 41 + x = 180 and solving for x
Strategy C 180 - 41 = 139 Using adjacent angles	Strategy D Parallel angels and solve for x (Leandra's picture)

5. **PRESENTATION ORDER:** *Which strategies do you hope to spotlight during the discussion? How will you sequence these strategies?*

Sequencing ideas: concrete to abstract, most common approach to least common approach, start with a common misconception
Sequence Order:

6. ANTICIPATE MISCONCEPTIONS:

Possible Misconceptions:	*Questions to push on misconceptions :*
360 - 41 *Or 90 - 41* *If using a protractor, measurements could be off.*	

APPENDIX E: LISA'S LESSON PLAN

1. SCRIPT THE LESSON - Launch, Explore Discuss Lesson Guide

LAUNCH (12 mins)	
Present to students the visual of the three parallel streets: Broadway, 4th, and third. Where there is an angle marked x and an angle marked y. Have students observe the image and write down what they notice and what they wonder. Think time (5 mins) Share at their tables for about 2 mins. Have students select one of their most interesting noticings or wonderings to share. Have them start with the student who got the most sleep the night before and move clockwise around the table. Whole-group discussion 5 minutes.	
EXPLORE - Monitoring Student Thinking Table	**Key Questions**
Explore #1 **Introduce the context of the problem:** The city of Chula Vista has asked you to create a skate path from the beach to a park. Your team measured angle x during your field work but forgot to measure angle y. How can you determine the measure of angle y? ● **Students will be provided scratch paper.** ● **Leandra will have the students fold the paper into crossed lines.** ● **Leandra will lead students in folding paper to create parallel lines and cutting and comparing** ● **Leandra will invite students to return to the original problem with their new knowledge** **Explore #2** ● **Introduce to students that angle x is 41 degrees. What is the angle measurement for angle y?**	❑ What different strategies did you try? ❑ What connections do you see? ❑ What do you wonder about the problem? ❑ Can you tell me why your team thinks…? ❑ What evidence do you have to support…? ❑ What does ___ represent in your ___ (drawing, graph, equation, etc.)? Other questions to explore/push student thinking: - How can you prove that the two angles are equal? - If I have a straight line, how many degrees are in a straight line? - Which angles were equal to each other in the paper folding, so which angles would be equal to each other? Extension: A second path is also being added along East J Street. What angle does the second path make with the skate path?

LAUNCH (12 mins)	
• **Leandra will look for a variety of strategies (listed at the top) to pull for students.**	

DISCUSS

Pull at least one student to share their strategy and open up for questions.
(if no questions from students, Leandra will ask the following, "How is this strategy similar or different from yours?")
Have a couple more share out.

Give out post-test

Presentation Expectations:

 Will all students in a group be expected to present/talk? What will students in the audience be expected to do?

 How might you use a double huddle to have the audience grapple with the idea shared?

Key Questions:

To launch the discussion:

- ❑ What is the same or different about these strategies?

To keep the conversation going:

- ❑ What is one thing you understand and one question that you have about __?
- ❑ Who can restate x's idea? What questions do you have?
- ❑ Are you convinced? Would you bet on this idea?

To connect, conjecture, & sum up:

- ❑ Are we able to make any conjectures?
- ❑ Do we see any connections between approaches?
- ❑ How does ___ connect to the visual?
- ❑ What are the big ideas and takeaways for you?
- ❑ In light of our takeaways, what would we title this lesson?

Other Questions:

APPENDIX F: CRCD MATH TASK RUBRIC

Culturally Relevant Cognitively Demanding (CRCD) Task Rubric

Description	High	Moderate	Low
Mathematics task explicitly requires students to inquire (at time problematically) about themselves, their communities, and the world about them.			
May draw from connections to other subjects and issues.			
Mathematics task draws from students' community and cultural knowledge			
Task may explicitly seek to add to this knowledge through mathematical activity.			
Task is mathematically rich and cognitively demanding, embedded in cultural activity.			
Task asks students to engage the discontinuity and divide between school and their own lives - home and school.			
Task is real-world focused, requiring students to make sense of the world through mathematics.			
The explicit goal of the task is to critique society - that is, make empowered decisions about themselves, communities and world.			

From Matthews, L.E., Jones, S.M., & Parker, Y.A. (2013). Advancing a framework for culturally relevant, cognitively demanding mathematics tasks. In J. Leonard & D. Martin (Eds.), *The brilliance of Black children in mathematics: Beyond the numbers and towards a new discourse.* Charlotte, NC: Information Age Publishing.

APPENDIX G: STUDENT OBSERVATION PROTOCOL

Observation Protocol

Exploring How CRCD Math Tasks Impact Students' Mathematical Knowledge and Engagement

Date

Time of Observation

Teacher

Specific Places Observed (use a separate protocol for each classroom observed)

The purpose of these observations is to find evidence of student engagement with culturally relevant, cognitively demanding math tasks. Specific examples are listed below each category. These are provided to guide the researcher and should not be considered the only possible manner in which engagement could be evidenced.

Sharing an Idea
Students are creating and using strategies and sharing those strategies with their peers. This can be seen either through a partnership, in groups, or sharing an idea during a whole class-discussion.

Staying on Task
Students are actively talking, sharing, listening, and working on the mathematical task. Students are not being distracted or having conversations that are off-topic.

Asking Questions
Students are asking questions to clarify ideas, to understand ideas deeply, and/or being skeptical of ideas shared.

APPENDIX H: LESSON STUDY PRE-BRIEF PROTOCOL

Mathematical Agency Improvement Community
Lesson Study Pre-brief
Facilitators Agenda

Why Lesson Study?
In order to learn more about how our students learn mathematical concepts deeply, we need to spend time listening to their thinking in different contexts and in response to different instructional environments. Lesson study is a powerful way to do this with colleagues and provides a structure for us to engage in cycles of inquiry and reflection in order to learn and grow as professionals in our field.

Overview of Lesson Study Cycle:
Pre-brief (today): Lesson study teacher shares their mathematical goal for the lesson and their learning culture goal. Participants do the math together, anticipate student thinking, and plan the lesson together.

Day of the lesson study: Briefly meet to confirm mathematical goal & learning culture goals. Lesson study teacher assigns each observing teacher a student or pair of students to focus on for the duration of the lesson.

Observe the lesson & collect data on student thinking: During the lesson the observing teachers are careful to abide by the norms of the lesson study:

- Respect the classroom atmosphere - silence phones and refrain from side conversations
- Arrive on time and stay for the entire lesson
- Resist the urge to help students or interfere with the natural flow of the lesson - be careful not to block students view of the board or the teacher
- Focus on how your assigned student is thinking about the mathematics - what do they say? What do they do? How do they react to the classroom routines/teacher moves/prompts?

Debrief: Block out an hour for the post-lesson debrief as soon as possible after the lesson. The lesson study teacher will have the opportunity to share first about how they felt the lesson went. This will be followed by an opportunity for participating teachers to share their observations of their focus student throughout the lesson. Following the teacher share out, participants engage in an open discussion around 1-2 key questions posed by the teacher. The lesson study teacher has the final word.

Protocol for Pre-Brief Day

5 min: Go over the rationale for lesson study and the overview of a lesson study cycle (above).

15 min: Do the math together and anticipate student thinking. Share possible strategies and sound bites as students may solve the problem.

10 mins: Review the problem and assess based on the CRCD Math Task Framework

30 min: Lesson study teacher shares their mathematical goal, learning culture goal, anticipated student thinking, potential sequence of student strategies/thinking for whole class discussion. Team modifies task and help to create the launch, explore, and discuss sections of the lesson.

APPENDIX I: LESSON STUDY DEBRIEF PROTOCOL

Mathematical Agency Improvement Community
Lesson Study Debrief Protocol
Facilitators Agenda

Norms For Participating in Lesson Study: During the lesson the observing teachers are careful to abide by the norms of the lesson study:

- **Respect the classroom atmosphere** - silence phones and refrain from side conversations
- **Arrive on time and stay for the entire lesson**
- **Resist the urge to help students or interfere with the natural flow of the lesson** - be careful not to block students view of the board or the teacher
- **Focus on how your assigned student is thinking about the mathematics** - what do they say? What do they do? How do they react to the classroom routines/teacher moves/prompts?

Debrief Protocol

Facilitator Frames the Debrief *(5 min)*
Teaching, by its very nature, is an act of vulnerability. Inviting others into our practice to observe can feel risky and destabilizing. However, these types of experiences also often lead to insight and growth for all participants. It is important as lesson study participants that we avoid making inferences and stay focused on observed student thinking. That way our questions and comments come from a place of curiosity and not a place of judgement.

Lesson Study Teacher Reflection *(10 min)*
The lesson study teacher shares what went well, what didn't, and any questions /wonderings on their mind that they would like the observers to discuss. *Facilitator takes note of specific questions/wonderings/themes the teacher would like the group to discuss.*

Observation Data *(10-15 min)*
Participants each have 1-2 minutes to share direct facts about their observed student(s). What did the student say or do? Which moments stand out as particularly important for understanding how the student made sense of the mathematics? No questions are posed at this time. Participating teachers listen silently to the each other's observations.

Discussion *(25 min)*
The facilitator revisits and confirms the lesson study teacher's 1-2 questions/wonderings for the following discussion. The lesson study teacher steps out of the circle of conversation to listen/takes notes while the observing teachers discuss the question/wondering in light of the student observation data.

Lesson Study Teacher Takeaways/Next Steps *(10 min)*
The lesson study teacher rejoins the group and shares his/her take-aways. They do not need to respond to any particular comment from the discussion, instead this is a space for the lesson study teacher to reflect on learnings and possible next steps.

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