# The Experiences of African American Students Engaging in Culturally Relevant Cognitively Demanding Mathematical Tasks

## ACCEPTANCE

This dissertation, THE EXPERIENCES OF AFRICAN AMERICAN STUDENTS ENGAGING IN CULTURALLY RELEVANT COGNITIVELY DEMANDING MATHEMATICAL TASKS, by AUDREA BANKSTON, was prepared under the direction of the candidate's Dissertation Advisory Committee. It is accepted by the committee members in partial fulfillment of the requirements for the degree, Doctor of Philosophy, in the College of Education & Human Development, Georgia State University.

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# THE EXPERIENCES OF AFRICAN AMERICAN STUDENTS ENGAGING IN CULTURALLY RELEVANT COGNITIVELY DEMANDING MATHEMATICAL TASKS

by

**AUDREA BANKSTON**

Under the Direction of Christine D. Thomas, Ph.D.

## ABSTRACT

This study investigated the experiences of African Americans students engaging in culturally relevant cognitively demanding mathematical tasks. Culturally relevant cognitively demanding (CRCD) mathematical tasks are high-level demanding tasks that explore mathematical concepts embedded with culture related to phenomena in their current lives (Mathews & Parker, 2013). The purpose of this study was to capture the students' experiences and to engage students in mathematical tasks that constitute "doing mathematics" or "procedures with connections (Stein, Smith, Henningsen, & Silver, 2009).

This qualitative case study is situated in critical race theory and constructivist theory of learning. In the study, I observed, recorded classes, and completed a content analysis about cognitively demanding mathematical tasks (Merriam, 2009; Merriam & Tisdell, 2016; Yin, 2014).

The African American students completed the culturally relevant cognitively demanding mathematical tasks in a virtual environment. It is expected that this study will contribute to the research surrounding the teaching and learning of mathematics for African American students. Additionally, the study will contribute to research about the usefulness of culturally focused lessons. Furthermore, this study is a counter-narrative surrounding African American students and mathematics.

INDEX WORDS: African American Students, Mathematical Experiences, Culturally Relevant Cognitive Demanding Tasks

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## DEDICATION

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# 1 Introduction

This study examined the mathematical experiences of African American middle school students engaging in culturally relevant cognitively mathematical demanding tasks. This study explored the students' mathematical experiences from a constructivist theory of learning lens. This chapter first highlights the narratives surrounding African American students and mathematics. A discussion of the deficit perspective of African American students and mathematics is followed by the counternarrative that describes African American students' success in mathematics. Next, there is a discussion about the need for African American students to have the opportunity to learn mathematics. The opportunity to learn mathematics allows students to engage in mathematical experiences (Törnroos, 2005). Thus, following the discussion of the opportunity to learn, the concept of mathematical experiences is operationalized, setting the stage for the mathematical experiences of African American students as a key component of this study's investigation. Finally, this chapter is concluded with discussions of the study's purpose, research questions, significance, and conceptual framework.

## Narratives of African American Students and Mathematics

There are two narratives surrounding the performance of African American students in mathematics. These dichotomous narratives are commonly referred to as deficit narratives and counternarratives. First, I describe the deficit perspective using three of the most known terms in the literature: a deficit discourse, the inferiority paradigm, and the achievement gap. Then, I discuss counternarratives based on research on pedagogical and social factors that promote African American students' success in mathematics.

***A Deficit Narrative***

Throughout history, a deficit discourse has surrounded the education of African American students. There are three critical areas in which the deficit narrative is situated. The three areas are deficit discourse, the inferiority paradigm, and the achievement gap.

Deficit discourse is the racialized perception that students of color are always lagging in performance and blames the deficiency on the students and their families (Delpit, 1995; García & Guerra, 2004). Deficit discourse is often portrayed in statistics and other literature that states African American students are behind their counterparts or even “at risk.” Martin (2009a) provided an example where research statements suggested that African American students did not have mathematical competency because of their own effort. Additionally, Stinson (2006) noted that “African American children, specifically African American male students, are often characterized as incapable of measuring up to schools’ predetermined goals and objectives and lacking the behavioral and social skills and life experiences to be academically successful” (p.485).

Another frame that describes African American students in mathematics education is the inferiority paradigm. The inferiority paradigm suggests that non-Whites are inherently inferior to Whites (Carter & Goodwin, 1994). In other words, the inferiority paradigm suggests that African American students cannot perform on the same level as their Caucasian counterparts. The inferiority paradigm is a continuous thread that has manifested itself into a frame such as achievement gaps (Bullock, 2019). In mathematics, the term achievement gap "is a well-publicized yet problematic term used to describe disparities regarding mathematics performance of groups of students” (Joseph & Cobb, 2019).

The term achievement gap infers that African American students are deficient at the beginning, implying that African American student success is dependent on the outcomes of Caucasian students (Martin, 2009b). Hilliard (2009) quickly stated that the gap is not between Whites and African Americans as tests often portray. Still, the gap is between African American students' capabilities and controllable factors. Hilliard (2009) recognized that the gap is not about capabilities but the criterion levels in which African American performance is measured. The issue is with the way excellence is measured for African Americans. Berry, Thunder, and McClain (2011) noted that there was "more focus on using achievement tests to pathologize Black children as being inferior, deficit and deviant" (p. 36). In mathematics education, the inferiority paradigm is perpetuated through the narrative about African American students' poor performance or achievement gaps (Bullock, 2019).

The inferiority paradigm also extends to the curriculum (Bullock, 2019). Non-rigorous curricula and low cognitive pedagogical practices are typically for African American students in mathematics. These curricula and practices are based on the assumption of the inferiority paradigm (Bullock, 2019). The inferiority paradigm assumes that African American students cannot perform rigorous activities and that African American students are a problem that needs to be fixed. Typically, African Americans' engaging in a mathematics curriculum are subjected to non-rigorous instruction that supports basic skills (Flores, 2007). For example, Anderson (2019) described a classroom where 85% of the students were African American. In that classroom, students were working on a worksheet that focused on just naming the number of edges of geometric shapes. When asked about skipping the rigorous questions, the teacher believed that the questions were too hard for the student (Anderson, 2019). The classroom scenario is a prime example of the assumption that African American students cannot engage in thinking activities or exercises.

Deficit discourse stems from the roots of slavery, in which many people justified the differences in learning based on the inferiority paradigm (Bullock, 2019). When referring to African American students in mathematics education, it is not uncommon to hear that African American students are inferior and that White excellence is the standard (Davis, 2019). Deficit discourse and the inferiority paradigm display African American students as always lagging behind their counterparts or unable to perform specific mathematical activities.

### ***The Counternarrative***

Despite the abundance of deficit narratives surrounding the performance of African American students in mathematics, there is a growing amount of research that highlights African American students' success in mathematics (Malloy, 1998; Berry,2008; Martin & McGhee, 2011; Jett, 2011; Stinson, 2008, 2011).

Several research studies focus on pedagogical practices such as engaging in problem solving and culturally relevant activities, where African American students were successful in mathematics (Malloy, 1998; Hubert, 2014, Morton, 2014). For example, Malloy (1998) investigated the successful use of problem-solving strategies with eight grade African American students. Students in this study were deemed successful because the students exemplified problem-solving strategies such as guess and check, working backward, and logical deduction to solve the problems correctly (Malloy, 1998).

Several other studies that focused on the success of African American students in mathematics involve students 'personal journeys of their mathematical success (Berry, 2008, Stinson, 2011; Jett,2011). The students in the studies were deemed successful due to their graduate work in mathematics. For example, Jett (2011) and Stinson (2008, 2011) utilized storytelling as a counternarrative to the discourse of African Americans not succeeding in math. The studies captured the stories that documented the factors of school, spiritual guidance, and mentors as contributing factors to the students' mathematical success.

**Opportunity to Learn**

Tate (2005) stated that having the opportunity to learn (OTL) is an "important construct influencing—and possibly explaining— the impact of instruction" (p. 14). Tate (1995, 2005) adopted three constructs to produce the OTL framework, which focuses on the time, quality of instruction, content covered, and strategies implemented. Even though time, content covered, and strategies implemented are important to provide students with opportunities to gain experience, this study will focus on the quality of instruction.

Quality of mathematics instruction is "pedagogical strategies that positively influence student achievement in school mathematics" (Tate, 2005, p. 19). Quality instruction characteristics include rigorous mathematical tasks and instructional practices focusing on mathematical reasoning and understanding. Strutchens (2000) suggested allowing students to use mathematics as an investigational tool related to race and other social concepts, providing students opportunities to justify and critique other students and understand multiple mathematical concepts. Tate (2005) declares that quality instruction is a significant factor supporting African American students' opportunities to learn mathematics.

High-quality mathematics instruction also connects real-world contexts (Berry & Walkowiak, 2012; NCTM, 2000). African American students' "cultural expressions are neither reinforced nor represented in school mathematics'' (Ladson-Billings, 1997, p. 700). Flores (2007) shared that the opportunity to learn mathematics is built on African American students' culture.

Cultural references in the African American students' mathematical experiences are vehicles to "explore topics that address their socio-cultural realities in and out-of-school contexts" (Essien, 2017, p. 7). African American students are often subjected to mathematics that focuses on mathematics skills without emphasizing problem solving (Berry, 2003a, 2008). African American students' engagement with mathematics can be enhanced when they engage with challenging content. Jackson et al. (2013) researched the relationship between implementing high-level tasks and participating in learning opportunities. These high-level tasks provide cognitively demanding opportunities to improve African American students' engagement with mathematics. In their study, Jackson et al. rated students' opportunities to learn after engaging in cognitively demanding tasks using a rubric. Students complete cognitively demanding tasks “to explain their thinking, make new connections, describe their process, or critique other ideas" (Orrill, 2015).

**Mathematical Experiences of African American Students**

Experience is a common word that can have many realities associated with it. The term experience can explain common work, relationships, and life phenomena. People's experiences could be very vague, or they could be very detailed. Merriam Webster (n.d.) defines experience as the "practical knowledge, skill, or practice derived from direct observation of or participation in events or a particular activity." After encountering an experience, a person gains some awareness or understanding of good or bad. Experiences do not have to occur within a single event; sometimes, people gain experience from a series of events. After reviewing several articles relating to the mathematical experiences of children, Thompson (1991) shared the different meanings of experience, which range from "awareness" to "a totality of events lived through by someone" (p. 352).

Researchers such as Martin (2009a, 2009b) request that research illuminates the mathematical experiences of African American students. The research surrounding the mathematical experiences of African American students can be examined under formal and informal contexts where achievement will be reframed to their actual participation in mathematics as African Americans (Martin, 2009a, 2009b). In addition to reframing the narrative surrounding mathematical achievement, Martin (2009a, 2009b) claims that focusing on African American students' mathematical experiences highlight the issues of racism and racialization that occur among African American students.

The mathematical experiences of African American students coin them as "doers" of mathematics (Martin, 2009a). In becoming "doers" of mathematics, the mathematical experiences of African American students first acknowledge that race hinders mathematical opportunities (Martin, 2009a). Second, mathematical experiences allow for the acknowledgment of the community knowledge of students (Martin, 2009a). Stinson, Jett, and Williams (2013) noted that the mathematical experiences of African American students are enhanced when there is a bridge between the knowledge from home and the teaching and learning in schools. Finally, the mathematical experience for African American students should empower them and provide opportunities to learn mathematics (Martin, 2009a).

**Problem Statement**

Banicky (2000) suggested that African American students have different educational experiences than their peers of other races. The different education experiences include inequity in the resources available to them and the curriculum's instructional experiences that are provided to them. The different educational experiences are due to African American students are more likely to experience inequities in funding, inexperienced teachers, lack of school resources, low quality of instruction, and lack of access to offered classes (Flores, 2007; Darling-Hammond, 2013; Ladson-Billings, 2013; Welner & Carter, 2013).

African American students tend to have issues with the teachers that serve them (Flores, 2007). Predominantly African American schools tend to have the least qualified teachers with little to no experience in pedagogy (Flores, 2007). Flores (2007) stated that 33.3% of minority students are taught by out-of-field teachers, which perpetuates students' low expectations due to their lack of comfort with the content subject. With these inexperienced teachers, low expectations in the classroom fuel the differences in educational experiences for African Americans (Flores, 2007). For example, low expectations are manifested through "giving high grades for work that in other schools would earn lower grades or would be more appropriate for younger students" (Flores, 2007, p. 34). Furthermore, low expectations are fostered when teachers' notion of helplessness for African American students results in skills-based instruction (Flores, 2007). Low expectations lead to African American students being unable to access high-level mathematics courses and constant placement in remedial courses (Flores, 2007).

Another issue for African American students is the need for high-quality instruction and time to utilize quality instruction from qualified teachers (Darling-Hammond, 2013). The National Council of Teachers of Mathematics (2012), a national professional mathematical organization that has provided standards for teaching and learning, calls for students "to receive high-quality mathematics instruction, learn challenging grade-level content and receive the support necessary to be successful" (p. 1). According to the National Council of Teachers of Mathematics (NCTM), all students should have the opportunity to learn mathematics through a challenging student-centered approach. Recommendations from Silva and Stein (1996) include students working with worthwhile tasks that promote thinking and problem solving. Additionally, African

American students should have access to high-quality mathematics that puts the students' lives at the center of instruction (Gonzalez, 2009). High-quality mathematics instruction expects “students to explore multiple perspectives, questioning the standard curriculum and helping students find their own voices and construct their own knowledge" (Gutstein, Lipman, Hernandez, & de Los Reyes, 1997, p. 718)

This study provided African American students with an opportunity to learn by engaging African American students in mathematical tasks from a cultural perspective. The mathematical experiences of eight African American students engaged in challenging mathematical tasks within a cultural context provided an opportunity to learn mathematics.

**Purpose and Research Question**

This study investigated African American students' experiences in mathematics with respect to the NCTM process standards as they engaged in culturally relevant, cognitively demanding mathematically tasks. The process standards include problem solving, communication, representation, reasoning and proofs, and connections. The process standards will be explained in detail in Chapter 2 of the literature review. Therefore, the research questions that guided this study are:

1. In what ways do we describe the mathematical experiences of African American students while engaging in culturally relevant and cognitively demanding mathematical tasks?
2. In what ways do the National Council of Teachers of Mathematics process standards become evident in the mathematical experiences of African American students while engaging in culturally relevant cognitively demanding tasks?

**Rationale**

Albeit there is scholarly research involving African American students' engagement in mathematics using culturally relevant pedagogy (Hubert, 2014; Tate, 1995; Terry, 2010), more research is needed to provide insight into students becoming "doers" of mathematics (Martin, 2009a). Specifically, there is a dearth of literature on the mathematical experiences of African Students in mathematics as they engage in culturally relevant, cognitively demanding mathematical tasks. Thus, the study contributed to and expanded the research surrounding African American students in mathematics as they engage as doers of mathematics while engaging in culturally relevant cognitively demanding tasks.

Researchers call for cognitively demanding tasks to be part of the instructional process; however, a quick literature search demonstrates that most of the research is focused on the teacher's creation or implementation as learners of such tasks, not a focus of students engaging in mathematical tasks (Ladson-Billings,1997; Mathews et al., 2013; Stein, Grover, & Henningsen, 1996; Stein, Smith, Henningsen, & Silver, 2009). Additionally, the research focusing on students and tasks is more than ten years old. For example, Stein et al. (2009) research where student gains were noticed after implementing tasks occurred in 2009.

Scholars such as Ladson-Billings (1995), Malloy (2009), Mathew (2009), Tate (1995), and Terry (2010) recommend that the instruction be related to the students' lives. This study allowed students to use mathematics to investigate current topics in their communities. Embedding culturally relevant content in mathematics learning helps the students see mathematics as a part of their community and contributes to their academic success (Gutstein, 2003; Mathews, 2003; Moses & Cobb, 2001; Tate, 1995; Terry, 2010).

## Conceptual and Theoretical Framework

This section discusses the conceptual and theoretical frameworks that directed this study. The conceptual framework is culturally relevant cognitively demanding mathematical tasks. A theoretical framework is the underlying structure of concepts and theories that inform a study (Merriam & Tisdell, 2005). The theoretical framework is the constructivist theory of learning and critical race methodology.

## Conceptual Framework

The conceptual framework for this study consists of two perspectives culturally relevant pedagogy and cognitively demanding tasks (Ladson-Billings, 2020; Mathews et al., 2013; Stein et al., 2009). Culturally relevant teaching includes features that add cultural context to mathematics instruction (Ladson-Billings, 2014). Additionally, the cognitively demanding task consists of a high level of cognitively demanding tasks (Stein et al., 2009).

Furthering the definition of mathematical tasks, Stein et al. (2000, 2009) developed four mathematical task categories. Adapted from Doyle's theory, academic tasks bring "attention to what students are expected to produce, how they are expected to produce it, and with what resources" (Stein et al., 1996, p. 460).

The first type of lower-level task is memorization. Memorization-level tasks consist of problems that are easy to solve without procedures and do not have any conceptual connections (Stein et al., 2009). For example, a typical memorization task would ask a student, “What are the decimal and percent equivalents for the fractions ½ and ¼?” (Stein et al., 2009, p.3). The students would respond with a simple answer that is either correct or incorrect.

The second type of lower-level task is procedures without connections. Procedures without connections tasks use algorithms to solve problems (Stein et al., 2009). The students would be asked to convert a fraction to a decimal to a percent (Stein et al., 2009, p.3). Just like memorization, the student's response would be a correct or incorrect answer.

The higher-level demanding tasks require more thought when solving problems. Procedures with connections "requires students to use procedures (or algorithms) in ways that build a conjectural understanding of important mathematical ideas" (Mathew et al., 2013, p. 127). For example, students might be asked to use a procedure for finding a percentage in meaningful real-world scenarios (Stein et al., 2009).

The highest level of cognitively demanding tasks is “doing mathematics” (Stein et al., 2009). Doing mathematics involves students engaging in "non-algorithmic, unpredictable" tasks and requires multiple ways of representing concepts (Mathew et al., 2013, p. 128). For example, students may be asked to research, present, and justify a better camera for the science club at their school based on the number of exposures needed for the project (Stein et al., 2009). In this task, the students should decide on the mathematical concepts based on the context relevant to the science club's needs. Students engaging in tasks that are considered "doing mathematics" are asked to "access relevant knowledge and experiences and make appropriate use of their knowledge and experiences while working through the task" (Stein et al., 2009, p. 6).

The task analysis guide in Figure 1 gives a more in-depth description of the characteristics of the categories of cognitive demand for various tasks.

**Figure 1**

*Task Analysis Guide*

| Lower-Level Demands | Higher-Level Demands |
|---|---|
| <u>**Memorization**</u><br>• Involve either reproducing previously learned facts, rules, formulae, or definitions OR committing facts, rules, formulae, or definitions to memory.<br><br>• Cannot be solved using procedures because a procedure does not exist or because the time frame in which the task is being completed is too short to use a procedure.<br><br>• Are not ambiguous. Such tasks involve exact reproduction of previously seen material and what is to be reproduced is clearly and directly stated.<br><br>• Have no connection to the concepts or meaning that underlie the facts, rules, formulae, or definitions being learned or reproduced. | <u>**Procedures With Connections**</u><br>• focus students' attention on the use of procedures for the purpose of developing deeper levels of understanding of mathematical concepts and ideas.<br>• Suggest pathways to follow (explicitly or implicitly) that are broad general procedures that have close connections to underlying conceptual ideas as opposed to narrow algorithms that are opaque with respect to underlying concepts.<br><br>• Usually are represented in multiple ways (e.g., visual diagrams, manipulatives, symbols, problem situations). Making connections among multiple representations helps to develop meaning.<br>• Require some degree of cognitive effort. Although general procedures may be followed, they cannot be followed mindlessly. Students need to engage with the conceptual ideas that underlie the procedures in order to successfully complete the task and develop understanding. |
| <u>**Procedures Without Connections**</u><br>• are algorithmic. Use of the procedure is either specifically called for, or its use is evident based on prior instruction, experience, or placement of the task.<br><br>• Require limited cognitive demand for successful completion. There is little ambiguity about what needs to be done and how to do it.<br><br>• Have no connection to the concepts or meaning that underlie the procedure being used.<br><br>• Are focused on producing correct answers rather than developing mathematical understanding.<br><br>• Require no explanations or explanations that focuses solely on describing the procedure that was used. | <u>**Doing Mathematics**</u><br>• require complex and non-algorithmic thinking (i.e., there is not a predictable, well-rehearsed approach or pathway explicitly suggested by the task, task instructions, or a worked-out example).<br><br>• Require students to explore and understand the nature of mathematical concepts, processes, or relationships.<br><br>• Demand self-monitoring or self-regulation of one's own cognitive processes<br><br>• Require students to access relevant knowledge and experiences and make appropriate use of them in working through the task.<br>• Require students to analyze the task and actively examine task constraints that may limit possible solution strategies and solutions.<br><br>• Require considerable cognitive effort and may involve some level of anxiety for the student due to the unpredictable nature of the solution process required. |

Implementing high-level cognitive demanding tasks has several benefits. One benefit of using mathematical tasks is the increased capacity for mathematical thinking and reasoning (Stein et al., 1996). Another benefit is the use of discourse amongst students. Students work with partners and groups to enact mathematical tasks (Stein et al., 1996). Another benefit is that enacting high-level mathematical cognitively demanding tasks promotes "the use of multiple-solution strategies, and multiple representations required that they explain or justify how they arrived at their answers" (Stein et al., 1996, p. 482).

The idea of using mathematical tasks embedded with cultural referents is not new. Brantlinger (2013) utilized the notion of including social justice embedded, culturally relevant mathematical activities in his study with a high school night geometry class. The class contained a mixture of students of various demographics. Brantlinger (2013) highlighted mathematical activities that combined statistical concepts with issues of race and recess where students in the class investigated the correlation of decreased recess times in African American schools. Brantlinger (2013) observed an increase in discourse and engagement while his student completed activities with a cultural referent.

Likewise, Enyedy and Mukhopadhyay (2007), in their study, used open-ended, culturally embedded tasks to investigate inequities in an urban area with 25 high school students. The researchers employed a Geographical Information System called "My World," which provided access to maps of their area. The students used statistical models to support or dispel their claims of graduation rates and income levels. Implementing mathematical tasks embedded with culture allowed the students to engage in personal and relevant discussions.

Mathews et al. (2013) produced a framework that blends rich tasks and cultural referents. Culturally Relevant Cognitively Demanding (CRCD) mathematical tasks combine culturally relevant pedagogy and cognitively demanding mathematical tasks emphasizing high-level tasks (Mathew et al., 2013). CRCD mathematical tasks concentrate on the fact that the tasks be "mathematically rich and embedded in activities that provide opportunities for students to experience personal and social change" (Mathew et al., 2013, p. 132). Moreover, the CRCD task requires students "to inquire about themselves, their communities, and the world about them" (Mathew et al., 2013, p. 132). Furthermore, CRCD "features empowerment toward students' culture" while "requiring students to make sense of the work and explicitly critique society" when engaging in mathematical tasks (Mathew et al., 2013, p. 132). Culturally relevant cognitively demanding tasks aim to create a bridge between their schools and their worlds through mathematics (Mathew et al., 2013). The conceptual framework is a guideline that analyzes if a task meets the criteria of a high demanding, culturally relevant task and aligns with the benefits of implementing cognitively demanding mathematical tasks.

Culturally relevant cognitively demanding mathematical tasks intersect culture and higher levels of cognitively demanding tasks. Figure 2 is a refinement of cognitively demanding mathematical tasks as it includes aspects of culture. The first aspect of the framework concentrates on the two categories that demonstrate higher levels of cognitive demand, procedures with connections, and doing mathematics (Stein et al., 2009). The second aspect of the framework renames the classification to include concepts relevant to students' lives (Mathews et al., 2013). Concepts relevant to the students' lives will honor their personal day-to-day experiences (Mathews et al., 2013). For example, students may use mathematics to investigate food deserts if there are no healthy food choices in their communities. The final aspect of the culturally relevant cognitively demanding mathematical tasks framework is the feature of a high level of cognitively demanding tasks infused with a cultural aspect (Mathews et al., 2013). For example, students experiencing a food desert in their community may use mathematics to design and grow a garden, so they have fresh vegetables in their community (Gallivan, 2020). CRCD mathematical tasks refined the description of high-level cognitive demanding tasks by appending cultural and community references to the procedures with connections and doing mathematics (Mathew et al., 2013). This addition "challenges students to ask relevant questions of themselves and the world around them" (Mathews et al., 2013, p. 132).

**Figure 2**

*Culturally Relevant Cognitive Demanding Mathematical Task Framework*

**Higher Level Cognitively Demanding Mathematics Tasks**
(from Stein et al., 2000)

**Procedures with Connections Concepts. Meaning and Understanding**
**"Require some degree of cognitive effort"** {p. 16). Require use of procedures to develop deeper understanding of mathematics concepts versus narrow focus on algorithms. Promotes use of multiple representations to develop this meaning. Successful completion of the task requires engagement with conceptual underpinnings of task.

**Doing Mathematics**
"Require considerable cognitive effort' (p.16). Solution process is not obvious and require complex, nonalgorithmic thinking strategies which reflect understanding of mathematical concepts. Solution process may be unpredictable and tasks: encourage a variety of strategies. Require students to draw from "relevant knowledge and experiences and make appropriate use of them in working through the task" (p, 16). Encourages students to examine task structure, solution, and strategy limits.

**Procedures with Connections Concepts. Meaning and Understanding of Mathematics, Self, Culture and Community**

**Doing mathematics for the purpose of becoming empowered intellectually, culturally, politically, and socially.**

**Features of Cognitively Demanding. Culturally Relevant Mathematics Tasks**

Task ls a mathematically rich, higher-level cognitively demanding, embedded in cultural activity.

Mathematics task explicitly requires students to inquire (at times problematically) about themselves, their communities, and the world about them.

Mathematics task draws from students' community and cultural knowledge. May draw from connections to other subjects and issues

Task features an empowerment (versus deficit or color-blind orientation) toward students' culture. Task may explicitly seek to add to this knowledge through mathematical activity.

Task asks students to engage and overcome the discontinuity and divide between school and their own lives - home and school.

Task is real-world focused, requiring students io_ make sense of 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).

**Theoretical Frameworks**

A theoretical framework is the underlying structure of concepts and theories that inform a study (Merriam &Tisdell, 2005). This section provides a discussion of the theoretical frameworks that directed this study. The first subsection discusses the constructivist theory of learning and its connections to teaching. The second subsection examined the second theoretical framework, critical race methodology. The discussion includes a brief historical context of critical race theory, the four basic tenets of critical race theory, and the appropriateness of this study. Finally, an overview of both frameworks is summarized as it pertains to mathematical experiences and culturally relevant cognitively demanding tasks.

***Constructivist Theory of Learning in Mathematics.*** The epistemological stance that guided this study is constructivism. Crotty (1998) suggested that constructivism “describes the individual human subject engaging with the objects in the world and making sense of them” (p.79). Additionally, constructivism considerations include “focusing on the meaning-making activity of the individual mind” (Crotty, 1998, p. 58). Constructivism is “about knowledge and learning; it describes what 'knowing' is and how one 'comes to know'" (Fosnot, 2005, p. 10). In other words, constructivism is "essentially about the limits of human knowledge, a belief that all knowledge is necessarily a product of our own cognitive acts" (Confrey, 1990, p. 107). Constructivists' ideas include that knowledge is constructed "through our experiences, and the character of our experience is influenced profoundly by our cognitive lenses" (Confrey, 1990, p. 107).

The constructivist learning theory suggests that "individuals create their new understandings based on an interaction between what they already know and believe" (Richardson, 2003. p. 1623-1624). In other words, individual understanding is connected to their prior knowledge and experience. The constructivist theory of learning in classrooms implies that "students are always constructing an understanding for their experiences" (Confrey, 1990, p. 111). According to Fosnot and Perry (2013), learners constructing their own knowledge may include:

- Learners raise their own questions, create hypotheses, and discuss their findings in small communities
- Learners exploring through challenging, open-ended investigations
- Learners reflect on their experiences through multiple representations
- Learners engage in discourse in which they prove and justify their ideas and experiences.

Additionally, learners from a constructivist perspective construct “big ideas” that are "generalized across experiences, which often require the undoing or reorganizing of earlier conceptions" (Fosnot & Perry, 2013, p. 79-80).

"Constructivists agree that mathematical learning involves actively manipulating meanings, not just numbers and formulas" (Davis, Maher, & Noddings, 1990, p. 187). In addition to the guidelines listed by Fosnot, a constructivist mathematics advocate in the classroom for "providing learning environments in which students can acquire basic concepts, algorithmic skills, heuristic processes, and habits of cooperation and reflection" (Davis et al., 1990, p. 187). Students' thinking should be evoked, and their mathematical capabilities should be helpful in future and unforeseen situations (Davis et al., 1990). Additionally, constructivists argue that “to do” mathematics is to conjecture – invent and extend ideas about mathematical objects –test, debate, revise or replace ideas" (Schifter, 2013, p. 164).

The constructivist theory of “doing mathematics” is synonymous with NCTM's process standards. The process standards provide details about students' acquisition of knowledge (NCTM, 2000). Students should utilize problem solving techniques to build new knowledge

(NCTM, 2000). Similarly, constructivists advocate for students to engage in open investigations (Fosnot & Perry, 2013). Furthermore, with the reasoning and proof standard, students should investigate conjectures and justify mathematical arguments (NCTM, 2000). Likewise, Fosnot and Perry (2013) contended that students should create and test their hypotheses in a constructivist classroom. The communication standard also requires students to communicate their ideas and thinking mathematically (NCTM, 2000). Equally, a constructivist classroom compels students to justify their ideas and think through discourse (Fosnot & Perry, 2013).

**Critical Race Methodology.** A critical race methodology is a theoretical approach that examines and accounts for “race and racism” in education (Solórzano & Yosso, 2002). To understand critical race methodology, first, begin with the basic tenets of Critical Race Theory. Five basic tenets are the foundation of critical race theory. These tenets are evident in most scholars' versions of critical race theory (Delgado & Stefancic, 2013; Ladson-Billings & Tate, 1995).

First, critical race theorists state that racism is "normal" (Delgado & Stefancic, 2013, p. 1). Racism is so ingrained in society that it looks natural to many people (Delgado & Stefancic, 2013). Racism is hard to confront since racism is not acknowledged (Delgado et al., 2012). Racism contributes to inequities (Ladson-Billings & Tate, 1995).

Second, critical race theorists acknowledge the concept of interest convergence. Derrick Bell (2004) discussed the concept of interest convergence in which people of color will benefit from racial justice only if the dominant group benefits. Bell (2004) stated that "…. the interest of Blacks in achieving racial equality will be accommodated only when that interest converges with the interest of Whites in policy-making positions" (p. 69). One example of Whites benefitting from Blacks' plights was Brown's historical account versus the Board of Education. Bell (2004) began by creating the theory of White privilege by giving the background of famous court cases "that reinforced Blacks' inferiority to Whites." After the historical account, Bell (2004) explained how the lawsuit began; the long nights spent searching for defendants and the lengthy court struggle after the historical account. Despite the decision, districts resisted desegregation by closing schools, creating voucher systems, and refusing entry for Black students.

Third, critical race theorists ascertain that critical race theory is the social construction of race and race products (Delgado et al., 2012). Even though people of color have different personalities and behaviors, society creates races and bestows the races with long-lasting artificial characteristics (Delgado et al., 2012). For example, people of color are deemed lazy, even though many have jobs to support their families.

Fourth, critical race theorists' "challenge to racial oppression and the status quo takes the form of storytelling" (Delgado & Stefancic, 2013, p. 3). Narratives are important because they give the experiences of African Americans, and they are easy to record. Counter-storytelling is a form of storytelling. Counter-storytelling is a "pedagogical tool that allows educators to better understand the experiences of their students" (Taylor, 2009, p. 10). These stories often challenge the majority story and bring awareness to the racism involved. Solórzano and Yosso (2002) discuss three counter-stories: personal, other people, and combined narratives.

Finally, critical race theory declares a critique of liberalism (Ladson-Billings, 1998). According to Delgado et al. (2012), liberals think the world exists in a color-blind society. In other words, equal treatment does exist for all people. According to Jett (2012), critical race scholars contend that the "dominant culture does not fully understand how liberty and equality functions" (p. 23).

Critical race methodology provides a way for marginalized groups' experiences to be understood by others (Solórzano & Yosso, 2002). Marginalized groups are “groups and communities that experience discrimination and exclusion (social, political, and economic) because of unequal power relationships across economic, political, social, and cultural dimensions” (National Collaborating Centre for Determinants of Health, 2022). Additionally, critical race methodology allows the researcher to “draw on the knowledge of people of color who are traditionally excluded as an official part of the academy” (Solórzano & Yosso, 2002, p. 37). Critical race methodology in education components includes the following:

1. Foregrounds race and racism in all aspects of the research process
2. Challenges the traditional research paradigms, texts, and theories used to explain the experiences of students of color.
3. Offers a liberatory or transformative solution to racial, gender, and class subordination
4. Focuses on the racialized, gendered, and classed experiences of students of color.
5. Uses the interdisciplinary knowledge based on ethnic studies, women’s studies, sociology, history, humanities, and the law to understand the experiences of students of color better (Solórzano & Yosso, 2002, p. 24)

The components challenge deficit narratives through counter-storytelling and other nontraditional means (Solórzano & Yosso, 2002).

Critical race methodology allows researchers to share marginalized students' experiences in various ways through storytelling known as a counter-story (Solórzano & Yosso, 2002). counter-story is “a method of telling stories of those people whose experiences are not often told (Solórzano & Yosso, 2002, p. 32). Furthermore, it is a tool that exposes and challenges dominant discourses that have been perpetuated in a racialized system (Solórzano & Yosso, 2002). counter-stories employ storytelling, a tradition in African American communities that provides a voice (Tate, 1997; Delgado & Stefancic, 2012; Dixson & Rousseau, 2006). Stories from marginalized groups can give different perspectives on the stories of the oppressors (Tate, 1997; Delgado & Stefancic, 2012; Dixson & Rousseau, 2006). Storytelling can give voice to silenced people, and once shared, they can establish similarities in other people's stories (Delgado & Stefancic, 2012). Stories allow the oppressed to share their experiences. Voice is commonly utilized to challenge the dominant group's stories (Dixson & Rousseau, 2006). Voice is used to assert and acknowledge "the importance of the personal and community experiences of people of color as sources of knowledge" (Dixson & Rousseau, 2006, p. 35). According to Ladson-Billings (1998), "the 'voice 'component of CRT provides a way to communicate the experience and realities of the oppressed, a first step in understanding the complexities of racism and beginning a process of judicial redress" (p. 14).

Counter-stories serve four functions. The four functions are: (a) They can build community among those at the margins of society by putting a human and familiar face to educational theory and practice, and (b) they can challenge the perceived wisdom of those at society's center by providing a context to understand and transform established belief systems, (c) they can open new windows into the reality of those at the margins of society by showing possibilities beyond the ones their lives and demonstrating that they are not alone in their position, and (d) they can teach others that by combining elements from both the story and the current reality, one can construct another world that is richer than either the story or the reality alone (Solorzano & Yosso, 2002, p,30).

There are different types of counter-stories and other people's stories in which the narrative focuses on someone's experiences with racism. They are often told in the third person; they are composite stories with different forms of data in which an author discusses racism from a social, historical, or political perspective and personal stories where the author shares his or her own personal experience of racism (Solórzano & Yosso, 2002).

Counter-stories are often created using "(a) the data gathered for the research process itself, (b) the existing literature on the topic(s), (c) one's own professional experience, and (d) one's own personal experience" (Solórzano & Yosso, 2002, p. 34). Davis (2019) contends that counter-stories can be "used to children's mathematical experiences which are not often told in the field or larger society" (p. 194). Furthermore, Davis states that "counter-stories can use research data, mathematics education literature, and researchers' personal and professional experiences" (p. 194).

In this study, the counter-stories evolved while the students were engaged in the CRCD mathematical tasks. The counter-stories are captured in my descriptions of the students' mathematical experiences as they engaged in doing mathematics. These counter-stories challenge the deficit and inferiority paradigm narrative surrounding African American students in which African American students are described as not being capable of engaging in rigorous mathematics. (Berry, 2003a, 2003b; Martin, 2009a)

**Summary**

African American students are generally exposed to low cognitive objectives and expectations when encountering mathematics. African American students must be given opportunities to learn mathematics, including time to engage with content and quality instruction to change these issues. Quality instruction includes rigorous mathematical tasks that expose students to reasoning and problem solving. Additionally, quality instruction embeds real-world problems relevant to students' lives.

Culturally relevant mathematical experiences give students the necessary time to engage with mathematics. Additionally, it provides students with quality instruction because of the connections to real-world problems. African American students who participate in culturally relevant mathematical experiences are exposed to high expectations. As a result, they have the tools to unpack community issues and are situated to become actively engaged in continuing resolutions to community issues.

A critical race theory methodology provided an avenue to illuminate the mathematical experiences of African American students participating in mathematical instruction. Data from this story created a counter-story of African American students. This case study allowed an investigation focusing on African American students' experiences with the mathematical task related to their culture.

# 2 REVIEW OF THE LITERATURE

Chapter 1 discussed the conversations surrounding African American students and mathematics education. Most of the research places African American students in a deficit light and suggests that African American students lag behind other students in mathematics performance (Delpit, 1995; Flores, 2007; Martin, 2009a). Additionally, the mathematics curriculum assumes that African American students are inferior to other students by offering non-rigorous options to African American students (Bullock, 2019). The research presented in chapter 2 provides a synopsis of mathematical experiences for all students. Next, the literature review focuses on African American students' engagement in mathematics. It begins with research that is situated around the learning preferences of students when it comes to mathematics education. From the learning preferences, it is noted that lessons embedded in culture are a preference for African American students. A brief overview of culturally relevant teaching and examples of African American students engaging in culturally relevant activities is discussed. Next, the best practices for creating mathematical experiences are discussed. Additionally, I share pedagogical practices that support African American students' experiences in learning mathematics. After a brief discussion of critical race theory and the need for critical race theory when researching African American students, I highlight counter-stories to the deficit narratives of African American students' experiences in mathematics.

## Characteristics of Quality Mathematical Experiences

During the late 1980s, researchers were charged with creating standards that support high-quality mathematics education (Research Advisory Committee of the National Council of Teachers of Mathematics [RAC], 1988). The RAC's (1989) objective was to improve all students' mathematics learning and create a standard of quality instruction. This committee's early work laid the foundation for a research agenda about instruction and learning that is still prevalent today (RAC, 1988). The standards provided a "framework for curriculum development and evaluation that is consistent with the goals of most efforts to enhance the mathematical experiences of underrepresented groups" (RAC, 1989, p. 371). The framework became the document known and utilized as Principles and Standards for School Mathematics (NCTM, 2000).

After the inception of the National Council of Teachers of Mathematics' first standards, researchers such as Hatfield (1991) began examining students' engagement in mathematics. Engaging in mathematics entails students "listening, looking, drawing, writing, asking, or stating" (p. 304). Additionally, student engagement in mathematics includes the following:

> abstracting, particularizing, simplifying, generalizing, assuming, defining, conjecturing, guessing, checking, denying, confirming, concluding, questioning, doubting, justifying, proving, remembering, applying, classifying, connecting, matching, visualizing, computing, estimating, differentiating, patterning, valuing, fearing, hating, risking, and complying. (Hatfield, 1991, p. 304)

Hatfield (1991) outlined the conditions for students to have a quality mathematical experience. Quality mathematical experiences come in two states of being - the emotional (feeling) state of the students and the inquiry (thinking) state of students (Hatfield, 1991). The student's emotional state consists of the descriptors connected to feelings, whether they are positive or negative (Hatfield, 1991). Examples of students' positive descriptors include the words “challenged,” “powerful,” and “useful” (Hatfield, 1991). Some examples of negative descriptors publicized by students include “frustrated,” “overwhelmed,” and “confused words.” High-quality mathematical experiences tend to be a more positive emotional state for students, during which students tend to describe mathematics learning in an optimistic light (Hatfield, 1991).

Displaying a positive emotional state involves a student having a purpose" (Hatfield, 1991, p. 307).

Students exemplifying a sense of purpose often asked questions such as:

> What am I going to be doing? Why am I embarking on the task before me? What might I find out from my activity? Where does this situation appear to fit into what I have experienced before? Why am I being asked to do these things? How might my efforts and results in this activity be of value to me now and in the future? (Hatfield, 1991, p. 308)

A sense of purpose is an important emotional element related to" 'meaning givers' in the student's life" (Hatfield, 1991, p. 307). For a student to achieve a sense of purpose, the mathematical activity shall be "'meaningful" in the student's life" (Hatfield, 1991, p. 307). Without a productive and purposeful mathematical activity, the student's mathematical experience is reduced (Hatfield, 1991, p. 307).

Hatfield (1991) described the "potential of success" as another important emotional element that nurtures quality mathematical experiences for students (p. 308). Students should see the success of constructing mathematical knowledge (Hatfield, 1991). Additionally, students should see their errors to succeed instead of experiencing the negative connotation of making mistakes. Teachers should foster a community that does not focus on correct answers but views mistakes as a learning process (Hatfield, 1991). One of the goals of culturally relevant teaching is to develop academic success for students.

The second condition for fostering quality mathematical experiences includes connecting cognitive and intellectual factors and students' inquiry state (Hatfield, 1991, p. 309). Students' first element of an inquiry state involves developing a problematic perspective (Hatfield, 1991). Students should have a "problematic perspective with each mathematical encounter" (Hatfield, 1991, p .310). The problematic perspective is that "the problem to be solved is 'within' " a student (Hatfield, 1991, p. 310). The student takes ownership of the problem, and the problem becomes very integral to the student. For example, a student becomes aware of the problem, struggles with it, reflects upon it, and probably solves it (Hatfield, 1991). In the sense of being problematic, the problem becomes a part of the student and gives the student a personal connection with "doing mathematics" (Hatfield, 1991). In being problematic, the student's thinking is enhanced and "develops the abilities or attitudes for engaging" in mathematics (Hatfield, 1991, p. 311). Participating in the problem-solving process of doing mathematics helps the students develop critical mathematical connections by evaluating and constructing their personal meaning of the mathematical concepts (Hatfield, 1991).

Engaging in self-conscious reflectiveness is the third inquiry element for fostering quality mathematical experiences (Hatfield, 1991). According to Hatfield (1991), "when students are engaged in intentional efforts to think about their experiences in order to highlight important actions and consequences, it seems that these perceptions have more potential for use on future occasions" (p. 311). Students who engage in self-conscious reflections wonder, "What might I do to help myself learn effectively" (Hatfield, 1991, p. 311). Self-conscience reflections promote the future use of mathematics (Hatfield, 1991). Furthermore, it provides an avenue for learning at a deeper level (Hatfield, 1991).

The literature reveals that quality mathematical experiences include key elements and conditions. The first element consists of the student's emotional state, causing a positive or negative emotional effect. The student's inquiry state includes having a sense of purpose, being problematic, and engaging in self-conscious reflectiveness. Likewise, mathematical experiences can be complex while advancing personal knowledge and problem solving.

**Creating Mathematical Experiences for All Students**

In creating mathematical experiences for students, the "activities" should allow students to invest in themselves so they have a "mathematical experience" (Konold & Johnson, 1991, p. 33). Additionally, the activities should be purposeful to the students, promote problem solving, and initiate reflectiveness. The National Council of Teachers of Mathematics (NCTM) shared specific conditions for students' mathematical learning experiences. According to NCTM (2014), mathematical experiences allow students to:

> Engage with challenging tasks that involve active meaning-making and support meaningful learning; connect new learning with prior knowledge and informal reasoning and, in the process, address preconceptions and misconceptions; acquire conceptual knowledge as well as procedural knowledge so that they can meaningfully organize their knowledge, acquire new knowledge, and transfer and apply knowledge to new situations; construct knowledge socially, through discourse, activity, and interaction related to meaningful problems; receive descriptive and timely feedback so that they can reflect on and revise their work, thinking, and understandings; and develop metacognitive awareness of themselves as learners, thinkers, and problem-solvers, and learn to monitor their learning and performance. (p. 9)

The guidelines for mathematical experiences promote teaching and learning as active processes (NCTM, 2014). Teachers create these mathematical learning experiences, mathematical knowledge, and understanding for their students through engaging tasks. Teachers can create these mathematical experiences by ensuring that individual components of the process standards are incorporated into their instruction.

The National Council of Teachers of Mathematics created guidelines that inform K-12 mathematics instruction. The guidelines known as the process standards describe how students should engage in mathematics content. The five process standards are problem solving, reasoning and proofs, communication, connections, and representation (NCTM, 2000). Table 1 displays the process standards.

**Table 1**

*NCTM Process Standards*

| NCTM Process Standards | |
|---|---|
| Problem Solving | **Instructional programs from prekindergarten through grade 12 should enable each and every student to—**<br>• Build new mathematical knowledge through problem solving<br>• Solve problems that arise in mathematics and in other contexts<br>• Apply and adapt a variety of appropriate strategies to solve problems<br>• Monitor and reflect on the process of mathematical problem solving |
| Reasoning and Proofs | **Instructional programs from prekindergarten through grade 12 should enable each and every student to—**<br>• Recognize reasoning and proof as fundamental aspects of mathematics<br>• Make and investigate mathematical conjectures<br>• Develop and evaluate mathematical arguments and proofs<br>• Select and use various types of reasoning and methods of proof |
| Communication | **Communication**<br>**Instructional programs from prekindergarten through grade 12 should enable each and every student to—**<br>• Organize and consolidate their mathematical thinking through communication<br>• Communicate their mathematical thinking coherently and clearly to peers, teachers, and others<br>• Analyze and evaluate the mathematical thinking and strategies of others;<br>• Use the language of mathematics to express mathematical ideas precisely. |

| NCTM Process Standards | |
|---|---|
| Connections | **Instructional programs from prekindergarten through grade 12 should enable each and every student to—**<br>• Recognize and use connections among mathematical ideas<br>• Understand how mathematical ideas interconnect and build on one another to produce a coherent whole<br>• Recognize and apply mathematics in contexts outside of mathematics |
| Representation | **Instructional programs from prekindergarten through grade 12 should enable each and every student to—**<br>• Create and use representations to organize, record, and communicate mathematical ideas<br>• Select, apply, and translate among mathematical representations to solve problems<br>• Use representations to model and interpret physical, social, and mathematical phenomena |

From Process - National Council of Teachers of Mathematics. (2000). Retrieved July 31, 2022, from https://www.nctm.org/Standards-and-Positions/Principles-and-Standards/Process/

The process standards recommend what students should be able to do. For example, the problem-solving process standard states that students should require thinking skills to solve problems (NCTM, 2000).

Teachers intentionally choose challenging and worthwhile tasks that promote the process standard for problem solving. A worthwhile task is a "project, question, problem, construction, application, or exercise that engages students to reason about mathematical ideas, make connections, solve problems, and develop mathematical skills" (NCTM 1991, pp. 24–25). Teachers should provide students with opportunities to investigate mathematics through a discovery approach using problems that develop mathematical concepts and procedural fluency (NCTM, 2000). The Research Advisory Committee of the National Council of Teachers of Mathematics (1988) implied that mathematics inequities stem from the disparities in implementing high-quality mathematical instruction. NCTM is an agency that influences mathematics education through its contributions to research and sharing mathematics teaching strategies (NCTM,1991; NCTM, 2000).

NCTM's recommendations state that students should have relevant mathematical experiences that promote high-quality mathematics through discourse. Teachers should ask "questions that help students find mathematics in their world and experiences" (NCTM, 2000, p. 53). Questioning promotes mathematical discourse as well. Discourse involves "the purposeful exchange of ideas through classroom discussion and other verbal, visual, and written communication" (NCTM, 2014, p. 29). Finally, teachers should create classroom experiences where "students are encouraged to explore, take risks, share failure and successes, and question one another" (NCTM, 2000, p. 53).

In supporting the connection standard, teachers may help students "build a disposition to use connections in solving mathematical problems rather than see mathematics as a set of disconnected, isolated concepts and skills" (NCTM, 2000, p. 64). Teachers build on students' prior knowledge and do not dwell upon already mastered skills (NCTM, 2000). Teachers should convey the importance of using different representations to bridge old knowledge to new knowledge. Furthermore, teachers should utilize activities focusing on more than one type of representation. Students have a choice of which type of representation they choose. Providing students with choice builds their interest in mathematics because African American students could present familiar information.

The process standards are aligned with some of the characteristics of high-quality mathematical experiences outlined by Hatfield (1991). Inquiry state for a student requires students to solve problems in which they become immersed in the problem itself. Likewise, the process standards also require students to solve problems relevant to the students. Furthermore, rich mathematical experiences involve engaging in intellectual and emotional processes such as conjecturing, analyzing, and connecting. Similarly, the process standards entail students making conjectures, observing connections between concepts, and evaluating mathematical arguments.

**African American Students' Learning Preferences**

The learning preferences for African American students emerged from several studies. For example, Strutchens and Westbrook (2009) concluded after a study of two African American students that the profiled students preferred to learn mathematics connected to their career goals and embedded their culture while challenging them cognitively. Similarly, Thompson and Lewis (2005) shared a similar story of an African American male student seeking access to a high mathematics course that would prepare him for his career choice of being a pilot. In both instances, the students wanted to learn mathematics that was relevant to them and would prepare them to succeed in life.

Berry (2003) provided an overview of African American students' shared learning preferences. The three preferences are activities embedded in culture, activities that foster relationships, and activities that embrace learning from a holistic perspective (Berry, 2003). African Americans have a distinct culture that differs from others (Shade, 1997). Allen and Boykin (1992) shared nine dimensions of interrelated African American cultural experiences. The nine dimensions are:

> (a) spirituality, a vitalistic (sic) rather than mechanistic approach to life (b) harmony, the belief that humans and nature are harmoniously conjoined; (c) movement expressiveness, an emphasis on the interweaving of movement, rhythm, percussiveness, music, and dance; (d) verve, the especial (sic) receptiveness to relatively high levels of sensate stim-

> ulation (e) affect, an emphasis on emotions and feelings; (f) communalism, a commitment to social connectedness where social bonds transcend individual privileges; (g) expressive individualism, the cultivation of a distinctive personality and a proclivity [or spontaneity in behavior; (h) orality, a preference for oral/aural modalities of communication; and (i) social time perspective, an orientation in which time is treated as passing through a social space rather than a material one. (Allen & Boykin, 1992)

Berry (2003a) noted that African American culture involves spiritualism, communalism, orality, and a connection with nature. African American culture is different from the mainstream culture that focuses on separateness, materialism, and written words (Berry, 2003a). Knowing the African American cultural experience is key to African American students' success. Since culture is an important aspect of African American students' lives, infusing activities based on their cultural experience is recommended (Berry, 2003a; Ladson-Billings, 1997; Malloy & Malloy, 1998). One significant aspect of African American culture is the community. Community cultural wealth is "an array of knowledge, skills, abilities, and contacts possessed and utilized by communities of color to survive and resist macro and micro-forms of oppression" (Yosso, 2005, p. 77). Bringing in knowledge from the community and culture can transform African American students' educational experience by including aspects of their lives in instruction (Yosso, 2005). For example, African American students can explore exponential growth by investigating their family tree, interviewing their elders, and researching census data (Leonard, 2010). Embedding the concept of community cultural wealth can happen by providing students an opportunity to solve open-ended problems relevant to their communities. Furthermore, incorporating African American culture can increase student learning when the learning strategies are “compatible with the cultural style of African American learners (Berry, 2003a, p.246).

African American students examine the big picture when solving issues in their lives. Learning from a holistic perspective is a preference for African American students (Berry, 2003a; Malloy & Jones, 1998). Holistic learners examine learning as concepts connected to a whole (Berry, 2003a; Malloy & Jones, 1998). In other words, the holistic learner examines the big picture instead of examining the smaller components. Participating in holistic learning entails students exploring various solutions to solve problems to achieve the essence of their experiences (Berry, 2003a). Holistic learners thrive on kinesthetic instruction and need concreteness to obtain new knowledge (Shade, 1997). African American students prefer "investigating mathematical conjectures as they relate to content tied to a larger whole," supporting a holistic perspective. When learners engage in field-dependent learning, they utilize experiences from their environment and information in context (Shade, 1997). Field-dependent learners are students who like to be surrounded by others during instruction (Thompson & Knox, 1987).

Moreover, field-dependent learners tend to be non-sequential and holistic thinkers (Shade, 1994). According to Shade (1994), African American students "need concepts and ideas assessed in totality or interrelationality (sic)" as field-dependent learners (p. 186). African American students also need content interaction (Shade, 1997). The notion of interaction lends itself to kinesthetic learning in which they need concrete imagery (Shade, 1997).

Relationships are important to the African American community because of their emphasis on family. African American students prefer a relational style of learning in their classroom experience because it mirrors the communities in which they live (Berry, 2003a; Ladson-Billings, 1997; Shade, 1997; Stiff & Harvey, 1998). The relational style of learning description is the "freedom of movement, variation, creativity, divergent thinking, inductive reasoning, and focus on people" (Berry, 2003a, p. 246). One advantage is that students can learn from each other

(Essien, 2017). Furthermore, collaboration fosters "learning because students were able to speak more freely to one another" (Essien, 2017, p. 16). African American students working in a collaborative environment is beneficial (Hurley et al., 2005). Hurley et al. (2005) noted that performance amongst African American students who engaged in collaborative learning performed better than those who worked individually. Collaboration emphasizes "interpersonal relationships, group identity formation, and a sense of shared responsibility" (Hurley et al., 2005, p 516). Working together, African American students are "drawn by their peers to different aspects of the problem, different relationships than they might have noticed on their own." (Hiebert, 1992, p. 444). When African American students work together, they engage in mathematical discourse and discussions. Mathematical discourse is the exchange of mathematical ideas and concepts through verbal and nonverbal communication (NCTM, 2014). Mathematical discussion and discourse support African American students' learning process (Cory, 2014; Essien, 2017; NCTM, 2000; Silver & Stein, 1996). Discourse helps "students evaluate and interpret the perspectives, ideas, and mathematical arguments of others and construct valid arguments of their own" (Cory, 2014, p. 20). Berry and Walkowiak (2012) stated, "discourse provides multiple points of engagement and is a central part of what students learn and how they understand mathematics" (p. 170).

The learning preferences of African American students are supported by the NCTM process standards and the characteristics of quality mathematical experiences (Berry, 2003a; Berry & McClain, 2009). As a result of African American students and other minorities being underserved in mathematics, NCTM (2009) has set guidelines and standards to address inequities in instruction provided to African American students. NCTM's process standards are a set of guidelines that emphasize ways of "acquiring and using content knowledge" (NCTM, 2000, p. 29).

The NCTM's process standards include the following standards: problem solving, reasoning and proofs, communication, connections, and representation (NCTM, 2000).

The process standard for problem solving supports a rich mathematical experience by engaging complex processes. The process standard for problem solving is comprised of building a new mathematical understanding by solving problems in context and utilizing various strategies to reach a solution (NCTM, 2000). Students engaging in the process standard for problem solving tend to "analyze situations carefully in mathematical terms" (NCTM, 2000, p. 53). Additionally, students engaging in the process standard for problem solving reflect on the process and adjust their approach if needed (NCTM, 2000). The process standard for problem solving supports African Americans' learning preferences since mathematical understanding and skills are done in context (Berry, 2003). Berry (2003a) recommends that "by experiencing problem solving in a social context, African American learners can understand the relevance of mathematics" (p. 247).

The reasoning and proof standard is a critical component of the process standards, engaging students in more cognitively complex thinking. The reasoning and proof standard supports a rich mathematical experience by formulating conjectures. The reasoning and proof standard requires students to "note patterns, structure, or regularities in real-world situations and symbolic objects" (NCTM, 2000, p. 57). Students engaging in the reasoning and proof standard perform investigations and make conjectures to develop arguments for mathematical concepts (NCTM, 2000). The reasoning and proof standard supports African American students' holistic perspective learning preference. For instance, African American students with a holistic perspective "can investigate mathematical conjectures related to content tied to a larger whole" (Berry, 2003a, p. 247).

Communication is important in problem solving because students learn how to explain their rational thinking verbally. The communication standard supports quality mathematical experiences by sharing thinking and understanding. The communication standard proposes that students disseminate their mathematical thinking and construct their understanding by listening to their peers. Students "gain insight into their thinking when they present their methods for solving problems, justify their reason to a classmate or teacher, or formulate a question about something that is puzzling to them" (NCTM, 2000, pp. 60-61). African American students prefer a relational learning style for learning (Berry, 2003a). In fact, "African American learners have a person-to-person orientation, preference toward oral expressions, social and affective emphasis, and are attuned to nonverbal communication" (Berry, 2003a, p. 247).

The connection standard involves seeing the "interplay among mathematical topics in a context that relates mathematics to other subjects, and their own interests and experiences" (NCTM, 2000, p. 64). Students gain the ability to visualize the usefulness of mathematics instead of viewing mathematics as a set of algorithmic procedures during the implementation of the connection standards. The connection standard supports African American students' preference for "a holistic view of mathematics that contextualizes mathematical ideas and concepts" (Berry, 2003a, p.248). In other words, the connection standards allow for African American students to learn mathematics immersed in their personal cultural experiences.

The representation process standard helps students connect to the concepts they are learning in a practical way that engages their interests. The representation process standard is a vehicle for expanding students' ability to think mathematically. Students can share mathematical concepts in a format that makes sense in their world by organizing, recording, communicating mathematical concepts and ideas, and interpreting real-life phenomena (NCTM, 2000). Representation in mathematics can come in any format, such as symbols, words, pictures, and diagrams. The representation process standard is consistent with the learning preference of African American students for "concrete imagery, creativity, verve, and divergent thinking" (Berry, 2003a, p. 248). Since mathematics can include visuals, graphs, communication, and problem solving, it is vital that "African American learners' mathematical experiences should include opportunities that allow them to use mathematics creatively" (Berry, 2003a, p. 248).

The literature revealed that African American students' mathematical learning preferences include embedded cultural activities. African American students benefit from a relational learning style and view information holistically (Berry, 2003a). NCTM's process standard provides behaviors students demonstrate when engaging in mathematical experiences. Table 2 demonstrates the association between NCTM's process standards and African American students' learning preferences.

**Table 2**

*Association between NCTM Process Standards and Learning Preferences*

| NCTM's Process Standards | African American Students Learning Preferences |
|---|---|
| Problem Solving | Cultural Embedded |
| | Holistic |
| Reasoning and Proof | Holistic |
| Communication | Relational |
| Connections | Holistic |
| | Relational |
| Representations | Holistic |

Table 2 represents the association between African American students' preferred learning styles and NCTM’s Process standards.

Embedding the learning preferences of African American students employs the NCTM's process standards to engage students in creating mathematical experiences. African American students need mathematical instruction presented in various ways to identify the instructional approach that best reflects their learning style. African American students are "given multiple teaching methods that will allow them to choose the method that suits their learning preferences and that students learn new ways of thinking and learning" (Malloy, 2009, p. 90). African American students learn mathematics from a holistic perspective that incorporates African American culture and opportunities to learn from their peers.

## Pedagogical Practices for African American Students

A commonality with research surrounding African American students and mathematics education are the recommendations that transform students into “doers” of mathematics. The pedagogical practices included students participating in culturally relevant activities, problem solving, and inquiry-based activities that provided opportunities for students' voices and created a learning community.

### *Culturally Relevant Teaching of Mathematics*

The learning preferences in mathematics for African American students emphasize a cultural connection to mathematical experiences. Research about African American students and mathematics consistently discusses incorporating culture with the aspects of the student's lives (Berry, 2003a; Ladson-Billings, 1997 &1998; Malloy, 2009; Malloy & Malloy, 1998). The research suggests that African American students have specific cultural strengths that are implementable in the classroom (Ladson-Billings, 1994). Culturally embedded strategies capitalize on the classroom's cultural strengths and can enhance academic and social experiences in mathematics (Ladson-Billings, 1994). Using culturally related instruction is to "foster empowering relationships with students and center teaching activity culturally to honor students' individual, community, and ethnic identities, while extending curriculum towards personal meaning, citizenship, and engagement (Mathew et al., 2013, p. 128). The purpose of culturally relevant teaching is to "frame teaching more broadly in ways that help students achieve academically, socially, politically, and culturally" (Mathew et al., 2013, p. 128). Culturally relevant instruction connects a student's day-to-day life with mathematical content.

In mathematics, culturally relevant teaching honors students' culture by providing mathematical content with "personal meaning, citizenship, and engagement" (Mathews et al., 2013, p. 128). According to Ladson Billings (1995), "culturally relevant pedagogy rests on three guiding principles: (a) students should experience academic success; (b) students should develop and maintain cultural competencies, and (c) students should develop a critical consciousness" (p. 160).

**Cultural Competence.** Cultural competence entails students maintaining their cultural integrity in achieving academic excellence (Ladson-Billings, 1995). Schools tend to reject African American culture (Ladson-Billings, 1995). For example, schools for African American students are places where they can "be themselves" (Ladson-Billings, 1995, p. 161). African American students can maintain their cultural competencies by incorporating their favorite song into a lesson, inviting community members to share stories and resources, or using mathematics to investigate a problem in the community (Ladson-Billings, 1995). Cultural competencies are important because they demonstrate how mathematics is helpful to students and why mathematics is important.

**Developing Critical Conscience.** Culturally relevant teaching requires students to go beyond the pursuit of academic excellence and develop a sociopolitical conscience (Ladson-Billings, 1995). Students should have the opportunity to "critique norms, values, mores, and institutions that maintain social inequities (Ladson-Billings, 1995, p. 162). Social justice instructional approaches in mathematics represent teachers' opportunities to provide African American students with culturally relevant learning experiences. Malloy (2009) recommended that "instruction includes social justice issues in their students' communities through democratic mathematics education (p. 113).

Similarly, Leonard, Brooks, Barnes-Johnson, and Berry (2010) suggested that social justice topics" can be used in mathematics classrooms to help students interpret and apply mathematical knowledge to answer questions that will potentially empower their lives and their communities" (p. 264). Gutstein (2003) developed a critical conscience with Latino students in his classroom. During the implementation, three pedagogical goals emerged. The three pedagogical goals for social justice teaching are to create social consciousness, create agency and cultivate identities (Gutstein, 2003). Gutstein (2003) reported a positive attitude from his students toward mathematics. The social justice lessons were the catalyst that prompted a viewpoint change toward mathematics (Gutstein, 2003). Even though the population was not African American students, it is important to note that culturally relevant teaching was a catalyst in changing students' mathematical viewpoints.

The cultural experiences of African American students provide teachers with an avenue to help students enhance their mathematical experiences. Using the students' experiences is a vehicle for conversations to "take place during the non-instructional time and provide opportunities for African American students to engage in discourse and explore topics that address their sociocultural realities in and out-of-school contexts (Essien, 2017, p. 7). The third component contributes to cultural relevancy for African American students in mathematics as a "critical tool for understanding social life, one's position in society, and issues of power, agency, and oppression" (p. 25). Creative teachers use mathematics like statistics to help students analyze trends that impact people's shared experiences within their cultural group. African American students with positive experiences in mathematics within challenging courses, including culturally relevant instruction taught by dedicated and skilled teachers, are more likely to have a more positive outlook on mathematics. Mathematics is a powerful tool that could challenge the dominant narrative of a marginalized group such as African American students. For example, Terry (2011) used mathematics to dispel the narrative that more African American males are in prison than in college. Using data from local colleges about enrollment and interviews, students graphed and interpreted data that showed that more African American males in their area were in college than in prison. Students in the study challenged the discourse through their investigation; hence, developing a critical conscience requires students to utilize mathematics to change unjust situations.

**Developing Academic Success.** Academic success is the "intellectual growth that students experience as a result of classroom instruction and learning experiences" (Ladson-Billings, 2014, p. 75). For African American students to experience academic success, African American students should be active learners (Ladson-Billings, 2014). For example, Terry (2010), using participatory action research methodology, shared the outcome of African American males critically investigating and critiquing data disseminated by the media and other sources. The African American male students were active researchers in the learning experience. The African American students demonstrated academic success through the ability to use mathematics as a tool to critique the world, promoting intellectual growth. In this case, the academic success of the young researchers promoted academic excellence (Terry, 2010).

Culturally relevant pedagogy supports three outcomes in the learning environments (Milner, 2011). First, Milner (2011) noted that students who experience culturally relevant pedagogy are empowered. Students have the ability "to examine more intently what they are learning, creating and to construct meaning to contribute to the multiple conversations in a classroom with a sense of agency, to succeed academically and socially, and to gauge contradictions and inequities both in school and outside of school" (p. 69).

An example of using culture in mathematics occurred in Hubert's case study (2014). The study captured the experiences of African American students after participating in a mathematics intervention using culturally relevant pedagogy. Even though the study was not isolated to only African American students, two African American students' voices were captured through student interviews. Hubert (2014) noted when referring to the African American students that "These two students also both expressed an increase in confidence from participating in culturally relevant mathematics instruction" (p. 334). Hubert (2014) noted that students enjoyed the family-oriented style of learning mathematics and working with their peers while learning mathematics relevant to them. From the study, six themes emerged: (a) Classrooms that resemble their homes; (b) caring; (c) opportunity to learn mathematics; (d) technology integration; (e) sureness; and (f) motivation (Hubert, 2014). In addition, all students that participated in the study experienced an improved attitude and interest in mathematics.

Moses-Snipes (2005) investigated the growth of elementary students after the African American students participated in a culturally relevant geometry lesson. The students were given a pre-test and a post-test during the study. It was determined that students experienced growth on the assessments, concluding that implementing the culturally relevant lessons benefited African American students.

Another example of using culturally relevant pedagogy occurred in Strutchen’s study. Strutchens (2000) described a situation in which students analyzed the number of liquor stores in their neighborhood. After analyzing the data, the students created a plan that included new tax structures to eliminate the high quantity of liquor stores (Strutchens, 2000). In this situation, the students used mathematics to propose a change in their community.

Bob Moses created culturally relevant instructional materials related to Civil Rights. The Algebra Project's instructional resources allowed minority students to translate their experiences into mathematical symbols and expressions in non-traditional ways (Moses & Cobb, 2001; Moses et al., 2009). Concerned with his children and their friend's mathematics issues and limitations, Bob Moses created the Algebra Project with the idea that everyone could do algebra (Moses & Cobb, 2001; Moses et al., 2009; Silva et al., 1990). The Algebra Project mimicked the civil rights work Bob Moses performed in the sixties when community and family were essential for minorities (Moses & Cobb, 2001). Moses proclaimed that mathematics was the new civil rights fight to prevent mathematics illiteracy from hindering African American children's opportunities (Moses & Cobb, 2001; Silva et al., 1990). For example, the Algebra Project's instructional materials included "a class trip as an experiential basis for learning addition and subtraction of integers" (Moses et al., 2009, p. 243). Working in groups, African American students were engaged in experiential learning, translating everyday language to mathematical language, and making connections through activities (Moses et al., 2009). The mathematical activities connected content to their everyday language and lives (Moses et al., 2009). For example, students take a trip in their neighborhood, represent their experience in their own language and pictures, and translate their pictures and symbols into mathematical expressions (Moses et al., 2009). The African American students participating in the project are exposed to "experiences that are human cultural experiences" (Moses et al., 2009, p. 254).

Terry (2010) utilized participatory action (PAR) research as his methodology with a group of students to provide a critical cultural activity mathematical experience during a summer program. Raygoza (2016) defines participatory action research for youth as "a problem-posing approach to education that challenges inequity by viewing youth as experts of their lived experiences and places power in their hands" (p. 127). The critical cultural activity explored contextualized data about the interest of the students. Students in the participatory action research project investigated the number of African American males in prison versus the number of African American males enrolled in college. This emphasis on African American males in prison through the mathematics prism reflected their need for mathematics to have a cultural connection to them. Students demonstrated the ability to tell "a different story about African American males in our communities using mathematics" (p. 84). In the study, the students utilized statistical concepts to dispel the myth that more African American males are in prison than college. Students were able to critique a prevalent narrative in the media (Terry, 2010). A byproduct of implementing PAR is the creation of experiential stories.

Embedding culturally relevant teaching in African American students' instruction can increase motivation, promote mathematical understanding, and develop critical consciousness. Students engaged in culturally relevant activities have demonstrated academic success (Hubert, 2014; Moses & Cobb, 2001; Moses, 2005; Terry, 2010). Additionally, using culture in instruction "supports student discourse and stronger teacher-student relationships" (Leonard et al., 2010, p. 263).

***Mathematical Tasks and Activities***

A common trend in the research for African American students and mathematics is the implementation of tasks with African American students. Stein et al. (1996) defined a mathematical task as "a classroom activity, the purpose of which is to focus students' attention on a particular mathematical idea" (p. 460). The activity does not change unless the mathematical orientation changes (Stein et al., 1996). African American students' engagement with mathematics can be enhanced when they engage with challenging content. Jackson et al. (2013) researched the relationship between implementing high-level tasks and participating in learning opportunities. These high-level tasks provide cognitively demanding opportunities to improve African American students' engagement with mathematics (Hatfield, 1991). In their study, Jackson et al. (2013) rated students' opportunities to learn after engaging in cognitively demanding tasks using a rubric. Students complete cognitively demanding tasks “to explain their thinking, make new connections, describe their process, or critique other ideas" (Orrill, 2015).

An educational reform project known as Quantitative Understanding: Amplifying Student Achievement and Reasoning (QUASAR) investigated the implementation of reasoning and problem-solving tasks for urban middle school students (Silver & Stein, 1996). The project utilized collaboration, communication, required justification, and multiple representations to implement complex mathematical tasks (Silver & Stein, 1996). The Quasar Project documented significant achievement when students utilized problem solving and discussion when learning mathematics

(Silver & Stein, 1996). Silver and Stein (1996) noted that "the number of students providing responses judged to be at the two highest-score levels more than doubled" (p. 505).

Wilson, Nazemi, Jackson, and Wilhelm (2019) used a comparative analysis methodology to investigate the classroom practices of teachers of successful African American students after the students participated in mathematical tasks versus classes where African American students were not so successful. The study concluded that attending to a student's context, creating a learning community, supporting language, and implementing and maintaining rigor in tasks contributed to the academic success of classrooms with African American Students.

Mueller and Maher (2009) implemented mathematical tasks using manipulatives with a group of African American elementary students. The study concluded that the students demonstrated problem solving, reasoning, and communication during the implementation of the tasks.

Malloy (2009) conducted a secondary analysis of a mixed method study where teacher instruction was observed to gather information about instructional practices of classrooms with successful African American students. The study examined several factors such as content, mathematical tasks, and interaction during the observations. It was observed that the classrooms of successful African American students developed conceptual understanding where teachers reflected on their practice, built learning communities, encouraged discourse, and included cultural experiences.

Morton (2014) investigated problem solving using mathematical tasks with African American students, particularly females using proportional reasoning. The study used a rubric to score the students' attempts at the problem, during which a score was generated to represent the level of conceptual understanding of mathematics. The study's conclusions revealed that students understood the importance of mathematics and had a cheerful disposition concerning mathematics (Morton, 2014).

### *Standard Based Instructions*

Berry (2003a &2003b) recommended that African American students engage in standards-based instruction in the learning of mathematics. As mentioned earlier, the National Council of Teachers of Mathematics (NCTM) shared standards that provide guidelines for teaching and learning mathematics. The five process standards are problem solving, reasoning and proofs, communication, connections, and representation (NCTM, 2000).

Gutiérrez (2000) used a case study methodology to examine the success of a math department for African American students. The findings suggested that a rigorous curriculum and standards-based instruction contributed to the African American students' success in the department.

## Critical Race Theory in Mathematics

Several studies in the literature review utilized critical race theory as the theoretical framework for examining the mathematical experiences of African American students (Berry, 2008; Hubert, 2014; Stinson, 2008; Strutchens & Westbrook, 2009). Continuing with the trend of using critical race theory as an analytical tool that examines African American students' experiences, I first provide a historical context of critical race theory. Second, I discuss the central themes or critical race theory related to mathematics education and share some mathematical counter-stories.

### *Historical Context*

Critical race theory is a derivative of critical legal studies that include racism in the analysis that exposes inconsistencies in its discourse (Dixson & Rousseau, 2006; Jett, 2012; Ladson-

Billings, 1998; Lynn & Parker, 2006). Derek Bell, Alan Freeman, and Richard Delgado have been credited as the founding father of critical race theory, placing a scholarly agenda at the center of legal dialogue (DeCuir & Dixson, 2004; Delgado, Stefancic, & Harris, 2012). The rationale for creating a new theory was to fight the subtle retraction of the civil rights gains in the sixties (Delgado et al., 2012). Tate (2005) suggested that "critical race theory presented a new paradigm using a variety of methodological tools, including storytelling, to inform understanding of racial injustice" (p.122).

***Critical Race Theory Features and Mathematics Education***

The definition of critical race theory in education is a "framework or set of basic perspectives, methods, and pedagogy that seeks to identify, analyze, and transform those structural, cultural, and interpersonal aspects of education that maintain the subordination of students of color" (Solórzano & Yosso. 2000, p. 42). Solórzano and Yosso contend that in education, critical race theory "challenges the common discourse on race and racism as they relate to education by examining how educational theory, policy, and practice are used to subordinate certain racial and ethnic groups" (p.40). Critical race theory in education recognizes that racism contributes to inequities (Ladson-Billings & Tate, 1995). Critical race theory highlights how curriculum practices such as tracking, teacher expectations, and testing maintain a racial hierarchy in education (Berry, 2008). Critical race theory in education also legitimizes people of color's experiential knowledge (Ladson-Billings & Tate, 1995). The experiences often are shared using stories. Ladson-Billings and Tate (1995) stated that people "name their own reality" by using "parables, chronicles, stories, counter-stories, poetry, fiction, and revisionist histories to illustrate the false necessity" (p. 57). According to Ladson-Billings (1998), stories are important because "they add necessary contextual contours to the seeming 'objectivity' of positivist perspectives" (p.11). Critical race theory often utilizes "storytelling, narrative, autobiography, and parable to expose and challenge the race's social constructions (Taylor, 2009, p. 8).

Critical race theory education interrogates issues where racism may be hidden and may operate on a systemic level (Davis, 2019). Critical race theory in mathematics education examines “how race and property rights provide an analytical tool for understanding social and school inequities” (Davis, 2019, p. 192). The property mentioned comes from the curriculum, which is often based on the dominant cultures (Ladson Billings & Tate, 1995). The following components of critical race theory from Solorzano and Yosso (2002) are relevant to mathematics education:

- Racism is a permanent fixture of schools, mathematics classes, and structures.
- CRT challenges the research and theories that situate African American students as deficient and tends to blame the marginalized group for the deficiency discourse.
- CRT consolidates African American students' race, gender, class, and mathematical experiences.
- CRT uses an interdisciplinary method to understand African American students’ mathematical experiences about race, racism, and life.
- CRT aims to achieve social justice outcomes for African American students in mathematics about society, schools, and learning spaces.

Davis (2019) suggested that in the field of mathematics education for students of color, researchers and scholars focus on the following: mathematical counter-stories, intellectual property, Whiteness as property, interest convergence, and “liberatory and social justice outcomes” (p. 193).

***Intellectual Property in Mathematics Education***

The focus on curriculum and pedagogy is important because the mathematics curriculum is a form of “intellectual property” that most affluent Caucasians can quickly obtain (Ladson-Billings & Tate, 1995). Intellectual property correlates the quality of curriculum with the value of the property surrounding the houses near the school (Davis, 2019. Schools with better property values have more course opportunities offered). At the same time, schools that serve high minority areas lack resources (Ladson-Billings & Tate, 1995). When examining curriculum as intellectual property, the rigor of the curriculum should be examined, and access to enriched classes should also be considered, not just the biases and stereotypes that occur (Ladson-Billings, 1998**).**

Many curricula, such as mathematics and other disciplines, support a dominant White culture, and critical race theory gives an avenue to challenge the hegemonic scripting in the curriculum (Ladson-Billings, 1995 & 1998). For example, Yosso (2002) used the lens of critical race theory to analyze and challenge the racial inequities in the curriculum and proposed a new, critical race curriculum. Yosso (2002) defined the term critical race curriculum as “the approach to understanding curricular structures, processes, and discourses, informed by critical race theory (CRT)” (p. 98). In addition to the curriculum, the areas of instruction utilize critical race theory as an explanatory tool. Critical race theory implies that "new research efforts are rejecting deficit models and investigating and affirming the integrity of effective teachers of African-American students" (Ladson Billings, 1998, p. 19).

Additionally, Ladson Billings (1998) gave a case of teachers that "remind students that mainstream society expects them to be failures and prod the students to succeed as a form of counterinsurgency" (p. 30). The area of instruction includes assessments. From the perspective of a critical race theorist, assessments are used to legitimize the deficits in the mathematical knowledge of African American students (Ladson Billings, 1995). Ledesma and Calderon (2015) revealed how White supremacy influences the curriculum in their literature review. For example, the review shows how U.S. history downplays the significance of interest convergence for voting rights.

### *Interest Convergence*

Since publishing the concept of interest convergence by Bell (1980), many scholars have utilized interest convergence in their discussion and research in education. For example, Horsford (2011) discussed the concept of interest convergence related to the integration of schools. Horsford (2011) noted that schools were never integrated, but African American students were merely placed into buildings to be there. Delgado and Stefancic (2012) mentioned that “many critical race theorists have applied it to understand many of the twists and turns of legal history” (p. 24). In a meta-synthesis paper, Berry et al. (2014) discussed the interest convergence reforms that were recently occurring in mathematics education. For example, the National Mathematics Advisory Panel provided recommendations for math instruction (Berry et al., 2014). However, the recommendations neglected to include the needs of African American students. The recommendations focused on technical solutions that did not focus on students' individual needs and non-technical factors such as societal conditions (Berry et al., 2014).

### *Critical Race Theory Mathematical Counter-stories*

Counter-stories allow the oppressed to share their experiences which sometimes go unheard (Solórzano & Yosso, 2002; Terry, 2011). Counter-stories are “grounded in the reality and realities of Black adults, providing many possibilities in mathematics (Davis, 2019, p. 193). Additionally, counter-stories can be a critical race theory methodology often used to counter the dominant narrative about African American students' performance. For example, Decuir and Dixson (2004) used a counter-story methodology to reveal the covert racial practices of two students, Barbara, and Malcolm, in a school that tried to display color blindness. The two students were often ignored in class as the only two African American students in a predominately white high school (Decuir & Dixson,2004).

Additionally, through counter-stories, Barbara revealed micromanaging the dress code for her and not for the Caucasian students dressed similarly. Duncan (2002) used storytelling to reveal the ingrained stereotypes that existed in the nineties in a Midwest high school. The study applied critical race theory as a "concrete step towards eliminating the oppression of black male students and providing space for their narratives in challenging the structures of domination in schools." (Duncan, 2002, p. 141).

Berry (2008) used the experiences of middle school boys to document their experiences of success and the mathematical construction of identities through the use of mathematical autobiographies. The counter-story of the two African American middle school boys who were successful in math included parental support, community resources, early educational experiences, and the will to be successful (Berry, 2003b &2008).

Terry (2011) used statistics as a counter-story with a group of African American males to dispel the discourse that more American males are in prison than in college. In the participatory research study, students were engaged in a social justice unit that allowed African American males to develop their understanding of statistics portrayed in the media and discover that the dominant discourse about African American males in prison was incorrect (2011). Terry (2011) noted that students should have the opportunity to tell stories that include them in mathematics.

Berry et al. (2014) conducted a meta-synthesis analysis of literature to document African American students' success in mathematics education. The analysis discovered eighty-seven studies using a variety of databases, and only eleven studies were noteworthy. In tabular form, the article defined success, ranging from males receiving good grades in high school and college mathematics to majoring in mathematics in college (Berry et al., 2014). Awareness and access, images, and agency were the three themes that emerged. The article discussed how students negotiated barriers after awareness, constructing identities, and selecting an agency (Berry et al., 2014).

Davis (2014) highlighted stories of African American males whose middle school mathematics classes were not challenging. One of the standard practices in the school was test preparation (Davis, 2014). The study allowed the students to share their stories that challenged the discourse they could not learn. The study revealed that the students were bored due to the modality of instruction. Davis (2014) pointed out that “Raheem believed Mrs. Green’s boring and unchallenging lessons made him and his peers uninterested” (p. 215). This statement contradicted the notion that the students were apathetic due to mathematical challenges.

Ballard’s and Cintron’s (2010) study focused on African American males receiving doctorate degrees from predominantly White institutions, using a phenomenological theoretical framework. The study is a counter-story to the narrative that African American males are not successful in non-historically Black colleges and university doctoral programs (Ballard & Cintron, 2010).

Strutchens and Westbrook (2009) used a counter-story to illuminate the experiences of three students in a classroom regarding the typical pedagogy given to African American students in a geometry class. Even though the classroom was teacher-centered, the purpose of the study was to share the students' voices and bring awareness to the issues and the lack of implementation of the proposed local and national standards.

Leonard, Walker, Bloom, and Josey (2020) give a counter-story of the mathematical experiences of five-generation women in a family. Despite the challenges of racism, both legal and hidden, the women demonstrated being mathematically literate, establishing a mathematical identity and resilience while providing examples of everyday usage of mathematics.

**Gaps in Literature**

Even though there is a growing number of scholarships surrounding African American students and mathematics education, there is still limited research discussing and sharing the mathematical experiences of African American students participating in mathematics (Martin, 2012; Berry, Pinter, & McClain, 2013). The literature revealed many studies examining African American students' teaching and learning from a teacher's perspective (Battey, 2013; Milner,2016; Sheppard, 2011).

Furthermore, studies such as Davis and Martin (2018) examined the racial underpinning of testing for African American students and provided implications for practice from a teacher's perspective. The implications suggested that teachers incorporate experiences relative to students and assist African American students in developing their math and racial identities. Additional studies such as Larnell, Boston, and Bragelman (2014) examined the stereotypes and threats against African American students as they play a role in their learning experiences.

Martin (2012) calls for research to learn “how black children can best attain and maintain excellence in mathematics” (p.60). This charge challenges the research community to focus on researching African American children attaining mathematical success. Even though there is an increase in researching African American children, a limited amount of research still focuses on African American students (Berry, Pinter, & McClain, 2013).

**Summary**

Evidence from the literature proposes that African American students' mathematical opportunities and experiences include culturally embedded tasks that promote problem solving. Including culturally relevant instruction and activities encourages students to develop academic success, develop a critical conscience, and build cultural competence (Ladson-Billings, 1995). African American students who have participated in culturally relevant instruction have demonstrated academic success.

Further evidence about African American students' learning preferences demonstrates that African American students prefer cultural embed, holistic, and relational style learning (Berry, 2003). These learning preferences connect to the NCTM's process standards that recommend students engage in mathematical experiences that promote problem solving, reasoning and proofs, communication, connections, and representations (NCTM, 2000). The primary vehicle for implementing the process standard is cognitively demanding mathematical tasks (NCTM, 2000; Stein et al., 2009).

Common themes and classroom strategies that emerged from reviewing the literature include community (group) learning, mathematical tasks, student discourse, peer and family support, and relevant instruction to the lives of the students (Moses et al., 2009; NCTM, 2000; Raygoza, 2016; Silva et al., 1990; Silver & Stein, 1996; Terry, 2010). The National Council of the Teachers of Mathematics recommends a student-centered approach to mathematics, where students engage in mathematical tasks and discuss their ideas with peers (NCTM, 2000). Mathematics learning for African American students should not be limited to skill development. The methods most appropriate for African American students learning mathematics provide choice in the learning process (Malloy, 2009).

In planning for a quality mathematical experience for African American students, a sense of purpose should be fostered and developed to form a personal connection to "doing mathematics" (Hatfield, 1991). A quality mathematical experience allows the students to take ownership of learning mathematics from their meanings and connections (Hatfield, 1991).

Since African American students are often depicted as deficient in mathematics, it was important to highlight and share the mathematics research from a critical race perspective (Flores, 2007). Critical race theory analyzes the racialized systems in mathematics education and provides an alternative narrative for people of color (Ladson Billings & Tate, 1995; Solórzano & Yosso, 2002; Dixon & Rousseau, 2006; Davis, 2019).

This study allowed African American students to share their mathematical experiences while engaging in culturally relevant, cognitively demanding tasks. The mathematical tasks allowed students to incorporate real-world phenomena while engaging in mathematics.

# 3 METHODOLOGY

This study investigated African American students' experiences engaging in culturally relevant cognitively demanding mathematical tasks. Using qualitative research, constructivist theory of learning, and critical race theory, I captured African American students' experiences enrolled in a summer camp that focused on science, technology, engineering, and mathematics (STEM). The following questions guided the investigation

1. In what ways do we describe the mathematical experiences of African American students while engaging in culturally relevant, cognitively demanding mathematical tasks?
2. In what ways do the National Council of Teachers of Mathematics process standards become evident in the mathematical experiences of African American students while engaging in culturally relevant cognitively demanding tasks?

## Qualitative Research

Qualitative research allows for research to be taken in the natural state, focuses on understanding from the participants' perspectives, and utilizes inductive thinking (Bogdan & Biklen, 2007; Merriam & Tisdell, 2016; Creswell, 2014). According to Merriam & Tisdell (2016), "qualitative researchers are interested in how people interpret their experiences, how they construct their worlds, and what meaning they attribute to their experiences" (p.15). This study focuses on the experiences of African American students after they engage in mathematical tasks from a constructivist theory of learning perspective.

Additionally, qualitative research allows the researcher to serve as the data collector and analyze the data (Bogdan & Biklen, 2007; Merriam & Tisdell, 2016; Creswell, 2014). Creswell (2014) maintained that "qualitative researchers collect data themselves through examining documents, observing behavior, or interviewing participants" (p.234). Researchers that employ qualitative research "gather data to build concepts, hypotheses, or theories rather than a deductively testing hypothesis" (Merriam & Tisdell, p.17).

Furthermore, qualitative research data is very descriptive (Bogdan & Biklen, 2007; Merriam & Tisdell, 2016; Creswell, 2014). The data collected and shared by the researcher is in the form of words and pictures instead of numbers (Bogdan & Biklen, 2007; Merriam & Tisdell, 2016; Creswell, 2014). Creswell (2014) communicated that the researchers gather "multiple forms of data, such as interviews, observations, documents, and audiovisual information rather than rely on a single data source (p.234). This study employed a variety of gathered data. African American students were observed as they completed the tasks. Additionally, recorded sessions were observed to describe the students engaging in the tasks.

Qualitative research occurs when the researcher goes to the participants' site where the experiences occur (Bogdan & Biklen, 2007; Creswell, 2014). This study allowed me, the researcher, to observe and implement the mathematical tasks during a summer Stem camp, collecting data at the participant's site. Finally, Merriam & Tisdell (2016) asserted that the theoretical framework structures the study's stance in qualitative research, and every study has a stance. The theoretical framework will "draw upon the concepts, terms, definitions, models, and theories of a particular literature base and disciplinary orientation" (Merriam & Tisdell, 2016, p. 86). The literature review revealed concepts about the experiences of African American students in learning mathematics. The theoretical frames that support these concepts are constructivism and critical race theory. These two frames are consistent with the characteristics of qualitative research. Recall that qualitative research focuses on the meaning-making that may occur through an experience (Merriam & Tisdell, 2016).

Similarly, the constructivist theory of learning asserts that students construct knowledge through their experience (Confrey, 1990). The common denominator between qualitative research and the constructivist learning theory is the participants' experience constructed and interpreted. Furthermore, critical race theory utilizes the voice of marginalized students to share their experiences. Likewise, qualitative researchers use words to "convey what the researcher has learned" (Merriam & Tisdell, 2016, p. 17).

**Case Study**

This study used a case study as the research design. Case study research is an "empirical inquiry that investigates a contemporary phenomenon (the 'case') in depth and within its real-life context, especially when the boundaries between the phenomenon and context may not be clearly evident" (Yin, 2014, p. 16). Additionally, Merriam (2009) stated qualitative case study research "is an in-depth description and analysis of a bounded system' (p. 40). This study involved African American students participating in a STEM summer camp daily in a mathematics class. The bounded system consisted of two mathematics classes that received the same instruction during the investigation. African American students in this case study registered to participate in the I AM STEM summer camp.

A case study methodology is appropriate when investigating "complex social units containing multiple variables" (Merriam, 1985, p.210). Furthermore, a case study methodology is an excellent "means for studying knowledge utilization "(Merriam, 1985, p.210). Case studies intend to reveal "about a phenomenon, the knowledge we would not otherwise have access to" (Merriam, 2009, p. 46). In this study, African American students enrolled in a summer STEM camp embodied the phenomenon most readers would not have access to since the stem camp targets a specific group.

Merriam (2009) further extended the definition of a case study by discussing case study research characteristics. Merriam (2009) mentioned that a case study is particularistic- “the focus of a particular situation, event, program, or phenomenon” (p.43). This study focused on African American students participating in culturally relevant cognitively mathematical tasks as the phenomenon occurrence. Also, Merriam (2009) stated that a case study should be descriptive – “the end of a case study is a rich ‘thick’ description of the phenomenon under study” (p.43). Upon completing the study, students' descriptions of their experiences were captured through interviews and observations and depicted in their narratives. Finally, another characteristic, according to Merriam (2009), is the heuristic which “illuminates the reader’s understanding of the phenomenon under study” (p.44). This study illuminates the understanding of the implementation of culturally relevant cognitively demanding mathematics tasks with African American students.

Case study research permits qualitative research generalizations (Cohen, Manion, & Morrison, 2018; Yin, 2014). Case studies “gain their potential for applicability to other situations by providing comparability and translatability” (Schofield, 2000, p. 75). One study's findings can apply to comprehend other situations (Schofield, 2000). According to Yin (2014), case studies are “generalizable to theoretical propositions” (p.21). “Lessons learned from a case study may apply to a variety of situations” (Yin, 2014, p. 41). Implementing this study permitted inferences based on the responses of the participants.

Case study research allows various data collection sources based on reality (Cohen et al., 2018). Case studies allow for the usage of documents, archival records, interviews, direct observations, participant observations, and physical artifacts (Cohen et al., 2018). The various data sources provide “evidence needed for the researcher to conclude” (Cohen et al., 2018, p. 387).

Additionally, the various data types provide credibility to the case study (Cohen et al., 2018; Yin, 2014). Data in this study revolved around observations and student artifacts.

Case studies research provides the opportunity to "see a situation through the eyes of the participants" (Cohen et al., 2018, p.380). This study brings attention to African American students who experience culturally relevant cognitively demanding mathematical tasks.

**Unpacking Culturally Relevant Cognitvley Demanding Mathematical Tasks**

Before implementing the tasks, the chosen tasks were analyzed for high-quality tasks that qualified as culturally relevant and highly cognitive demanding tasks. Culturally relevant cognitively demanding criteria are supported in the above Graffiti task. According to Mathews et al. (2013), cognitively demanding, culturally relevant tasks should have the following features:

- Tasks are mathematically rich, high-level, cognitively demanding embedded in cultural activity
- Tasks are procedures with connections or doing mathematics according to the Task Analysis Guide
- Mathematics tasks explicitly require students to inquire (at times problematically) about themselves, their communities, and their world.
- Mathematics tasks draw from the students' community and cultural knowledge
- Tasks feature empowerment, adding to their knowledge through mathematics
- Tasks ask students to engage and overcome the discontinuity and divide between school and their own lives at home and school
- The 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 makes empowered decisions about themselves, communities, and the world (p.133).

Each task was rated to determine if the task was cognitively demanding and culturally relevant using the Culturally Relevant Cognitively Demanding Mathematical Tasks features as a guide. Below is the Graffiti Mathematics task, adapted from the NCTM's Graffiti and Mathematics assignment (Bakewell, 2008). Table 3 shows the task that was provided to the students.

**Table 3**

*Graffiti Task*

| **Graffiti Task** |
|---|
| ***<u>Background Information</u>***<br>Graffiti has a rich history in personal expression and designs of mathematics. Graffiti artists find pride in their messages, as they often pertain to social issues or injustices. If defined as writings on the wall, graffiti dates back to ancient Rome. The urban graffiti known today, characterized by spray paint and vivid colors, appeared first in New York City in the 1960s. Taki 183, who lived in the Washington Heights district, worked as a messenger. As he traveled throughout the city, he would write his name at his various stops, beginning the practice of "tagging. Graffiti is marked by ideas of symmetry, balance, patterns, measurement, and proportion." (Bakewell, 2008, p. 1)<br><br>***<u>Task</u>***<br>Your task is to use mathematical equations to create graffiti art in the Cartesian Plane |

Table 4 demonstrates the alignment of the lesson objective with the Culturally Relevant Cognitively Demanding Mathematical task features and the rationale for choosing the feature. For example, students explored the history of graffiti, where they learned that an African American male created the first graffiti mural. This discovery allowed the students to discover a historical fact about the African American Community.

**Table 4**

*Graffiti Task CRCD Features*

| Lesson Objectives | CRCD Features | Rationale |
|---|---|---|
| Students explore the history of graffiti | Mathematics tasks require students to inquire about | Students learn the history of who created the first Graffiti |

| Lesson Objectives | CRCD Features | Rationale |
|---|---|---|
| | themselves, their communities, and the world around them (Mathew et al., 2013) | mural was an African American male |
| Students identified different mathematical features in present-day graffiti murals | Mathematics tasks require students to inquire about themselves, their communities, and the world about them (Mathew et al., 2013) | During the implementation of the task, current events focused on murals depicting George Floyd. George Floyd was killed by police officers, which sparked national protests (Sayej, 2020). The mural was important to the African American community because it was the backdrop to many community speeches and a memorial to George Floyd's life (Sayej, 2020). |
| Students explore graffiti murals in urban cities | Mathematics draws from the student's community and cultural knowledge (Mathew et al., 2013) | The statement from the task required students to think about street art posted in their communities. |
| Students explore equations of functions using art | Tasks is a mathematically rich high-level, cognitively demanding embedded in the cultural activity “requires students to access relevant knowledge and experiences and use them in working through the task” (Mathew et al., 2013; Stein et al., 2009, p.6). | Students used their prior knowledge of graphing to create a picture by exploring equations with the domain and range restrictions. |
| Students will use Desmos (graphing technology) to recreate their graffiti picture | Task asks students to engage the discontinuity and divide between school and their lives-home and reality | Students select pictures that are relevant to them |
| Students used Desmos (graphing technology) to recreate the graffiti picture that is relevant to their lives by manipulating the equations | Tasks are mathematically rich high-level, cognitively demanding embedded in the cultural activity. “Doing Mathematics,” where the task | Students consistently examined their pictures and the graphing constraints that may occur. |

| Lesson Objectives | CRCD Features | Rationale |
|---|---|---|
| | requires "students to analyze the task and actively examine task constraints that may limit possible solution strategies and solutions" (Mathew et al., 2013; Stein et al., 2009, p.6). | |
| Students were testing different equations to create a replica of the drawing in a non-algorithmic manner | Tasks are mathematically rich high-level, cognitively demanding embedded in the cultural activity. "Doing Mathematics," where the high-level cognitively demanding tasks require "complex and non-algorithmic thinking (i.e., there is not a predictable, well-rehearsed approach or pathway explicitly (Mathew et al., 2013; Stein et al., 2009, p.6). | Students created and graphed mathematical equations based on their pictures in the Graffiti Tasks. Students were testing different equations to create a replica of the drawing in a non-algorithmic manner. |

**Table 5**

*Covid 19 Task*

| **Covid-19 Disparities with African Americans** |
|---|
| ***Background Information***<br>• Black Americans continue to make up a disproportionate share of Covid-19 fatalities as the number of deaths from the coronavirus pandemic exceeds 100,000 in the U.S., according to an analysis of CDC data.<br>• Nearly 23% of reported Covid-19 deaths in the U.S. are African American as of May 20, even though black people make up roughly 13% of the U.S. population, according to the data.<br>• Conditions such as diabetes, hypertension, and asthma that tend to plague African Americans more than other groups could contribute to more Covid-19 deaths. Income inequalities and disparities in access to health care tend to hurt minority and lower-income populations more than others. |

| Covid-19 Disparities with African Americans |
|---|
| • Dr. Anthony Fauci, the nation's leading infectious disease expert and member of President Donald Trump's coronavirus task force, said in April that the coronavirus outbreak is "shining a bright light" on how "unacceptable" the health disparities between blacks and whites are. (Lovelace, 2020)<br><br>***Task***<br>a) Using reputable resources such as WHO, the CDC, or John Hopkins, collect data points pertaining to the infection rate of African Africans and other minorities compared to the Caucasian population. Compute the rate of the data points you found. Does the data correctly reflect the percentages presented above? Are African Americans and other minorities currently contracting the covid-19 at a higher rate?<br>(b) Research factors that slow the spread of Covid -19 for African Americans and other minorities. What are some things that can be done to slow the spread?<br>(c) Create an infographic using the information you found to share the information you research with family and friends. |

The second task implemented during the I AM STEM summer camp was the Covid-19 task. The Covid-19 Disparities tasks ask students to investigate the data portrayed in the news and create an infographic using the information discovered. Table 6 evaluates the daily lesson objectives using the conceptual framework's key features of the culturally relevant cognitively demanding mathematics task. The information in table 6 indicates the lesson objectives and alignment to the culturally relevant cognitively demanding mathematical task features. For example, in exploring the disparities among the ethnic groups, students investigate information that may affect their communities and families. Additionally, the covid 19 pandemic revealed healthcare disparities for African Americans and brought the issue to the forefront (Vasques-Reyes, 2020)

**Table 6**

Covid 19 Task culturally relevant cognitively demanding (CRCD)Features

| Lesson Objectives | CRCD Features | Rationale |
|---|---|---|
| Students explore the disparities amongst ethnic groups | Mathematics tasks require students to inquire about themselves, their communities, and the world around them (Mathew et al., 2013) | Covid-19 was a new virus that interrupted many lives. During the early part of the pandemic, schools were closed, hospitals were full, and jobs were closing. African Americans were dying at an alarming rate at the expense of maintaining the economy (Ortiz & Jessup, 2022). The topic of Covid-19 was relevant to students because their lives were interrupted by the closures |
| Students completed Demos Activity on modeling data | Tasks is a mathematically rich high-level cognitively demanding embedded in the cultural activity "Doing Mathematics," requires students to explore and understand the nature of concepts, processes, or relationships" (Mathew et al., 2013; Stein et al., 2009, p.6) | Students used graphing to plot and graph data points |
| Students researched and analyzed data | Tasks is a mathematically rich high-level cognitively demanding embedded in the cultural activity "Doing Mathematics," requires students to explore and understand the nature of concepts, processes, or relationships" (Mathew et al., 2013; Stein et al., 2009, p.6). | Students researched information using a reputable source. Once students collected their data students had to decipher the meaning of the data points. Students inferred the information and made conjectures about the information |

| Lesson Objectives | CRCD Features | Rationale |
|---|---|---|
| Students will create infographics based on the data collected | Tasks is a mathematically rich high-level, cognitively demanding embedded in the cultural activity "Procedures with Connections," usually are represented in multiple ways, making connections among multiple representations help to develop meaning" (Mathew et al., 2013; Stein et al., 2009, p.6). | Students will collect data and determine what is important to share on an infographic |
| Students communicate their findings with the class | The task is real-world focused, requiring students to make sense of the world through mathematics. The explicit goal of the task to critique society is to make empowered decisions about themselves, communities, and the world (Mathew et al., 2013) | Students will share the information questioning some of the rationales from major new sources. |

Both tasks were analyzed in the tables above, demonstrating the features of the culturally relevant cognitively demanding mathematical framework. For example, the tasks are higher-level cognitively demanding, requiring students to access and use relevant knowledge and experiences (Stein et al., 2009). In the Graffiti task, students used the new knowledge of graphing to create a picture by producing equations with domain and range restrictions. In the Covid 19 task, students accessed and analyzed data to evaluate the disparities. Another feature of higher-level cognitively demanding tasks is analyzing the tasks for limits and constraints with possible solutions (Stein et al., 2009). During the Graffiti task, students explored and examined mathematical constraints during the graphing process, a characteristic of higher-level cognitive thinking (Stein et al., 2009). Students consistently examined their pictures and the graphing constraints that may occur. The Covid 19 task allowed students to examine the constraints of reasonable data. Finally, higher-level cognitively demanding tasks require complex and non-algorithmic thinking" (Stein et al., 2009, p.6). In the Graffiti task, students created mathematical equations based on their pictures in the Graffiti Task in which they could not use set procedures. In the "Covid-19 Task, students utilized real-world data to compare ethnic groups as well as confirm or dispel the statistics reported in the news media

Both tasks exemplify a connection to culture and draw from the students' community knowledge (Mathew et al., 2013). The graffiti task asked students to locate and create pictures they may see in their community or like. The Covid-19 task asked students to research the disparities in minority communities and present the information as an infographic.

**Research Context**

This study occurred during the summer of 2020 within the summer camp of I AM STEM. The informal summer camp I AM STEM is a community-based program that aims to increase representation in science, technology, engineering, and mathematics among minority students (King & Pringle, 2018). The importance of hosting a community-based program such as I AM STEM is to bridge science, technology, engineering, and mathematics content with communities that do not have access to culturally based social justice enrichment activities (King & Pringle, 2018).

I AM STEM began over seven years ago, with its first program occurring in a face-to-face environment. Students who participated in the early programs range from kindergarten to twelfth grade. The summer camp marketing targeted populations where statistics were dismal regarding income and education (King & Pringle, 2018). There are no selection criteria for the summer program. It is an open program that enrolls anyone that would like to participate in enrichment activities.

I AM STEM's mission and purpose are to engage underserved students in problem-based learning with experiential learning in science, technology, engineering, and mathematics (King & Pringle, 2018). The classes represented in the I AM STEM camps are diverse. Past courses included black history, ethnomathematics, storytelling, and forensic science from a problem-based and inquiry-based learning perspective (King & Pringle, 2018; I AM STEM, 2022). Students who have participated in the I AM STEM camp follow a schedule. Typically, the classes are one hour, and students take four classes.

Instructors that teach for the I AM STEM camp are certified instructors in their field who are passionate about enriching students and share best practices that include cultural awareness and engaging students (I AM STEM, 2022). Selected instructors receive professional development in culturally relevant instruction and engaging students in non-threatening instruction (King & Pringle, 2018).

Before the pandemic, I presented at several conferences. The topics included culturally relevant and ethnomathematics activities. My entree with the I AM STEM program occurred after I assisted with the planning and designing of lessons for other instructors. After collaborating with the director, I was afforded the opportunity to instruct students in mathematics at a virtual summer camp.

The I AM STEM program was delivered in a synchronous virtual learning environment. Synchronous learning environments simulate face-to-face classrooms in a virtual format with whole group activities and discussions (Shamir-Inbal & Blau, 2021). Presenters and students using synchronous learning could present and demonstrate information (Shamir-Inbal & Blau, 2021).

There are several benefits to synchronous learning. One benefit is access to many learners (Cavanaugh, Barbour, & Clark, 2009; Shamir-Inbal & Blau, 2021). Students and teachers can log in from any location with internet service. Another benefit is the creation of self-regulated learners (Shamir-Inbal & Blau, 2021). Self-regulated learners monitor their progress, maintain their behavior, ask questions, and allocate time to complete tasks (Zimmerman & Schunk, 2011). Finally, synchronous learning provides high-quality learning opportunities (Berge & Clarke, 2005). Students will have access to rigorous activities and resources that may not be available in their area or school (Berge & Clarke, 2005)

Popular synchronous learning environments include platforms such as Zoom, allowing two-way conversations with video conferencing components (Shamir-Inbal & Blau, 2021). Due to the climate of Covid-19, the research setting took place through an online platform using Zoom. Students had a course schedule to follow, where they would utilize a link for the online classroom environment. The Zoom platform allowed students to interact with the facilitator (researcher) and participate. Students had the opportunity to share their screens, share their work, and work in groups on the CRCD mathematical tasks. The platform allowed the facilitator to use breakout rooms to simulate group work. Additionally, the Zoom platform allowed shared videos, pictures, and websites. Finally, students could talk or "chat" with the instructor.

The students of the summer camp study were recruited through an online campaign that offers a four-week STEM camp for kindergarten to high school students. The students voluntarily signed up for the camp using a registration form. After registration, students were assigned to a science and mathematics class based on their grade levels. All students with the camp participated in classes focused on culturally relevant mathematical tasks and science instruction. Students were engaged as middle-grade level students in the summer camp. Table 7 shows the population and demographics of all students enrolled in the summer camp at the middle-grade level.

**Table 7**

*Middle-Grade Summer Camp Registrants*

| **Gender** | **Race/Ethnicity** | | | | |
|---|---|---|---|---|---|
| | African American | African American Biracial | African American Hispanic | Biracial | White |
| **Male** | 43 | 0 | 0 | 1 | 7 |
| **Female** | 39 | 1 | 1 | 3 | 0 |

***Study Participants***

The students in this study were middle school students from families with different educational and socioeconomic backgrounds. The students were engaged during the two-week instruction of the task implementation in video and self-identified as African American during the secondary observations. The chosen students had their cameras on and contributed verbally or in the chat.

Students in this study were African American students between the ages of ten and thirteen from various locations. The students voluntarily registered and attended the program through an online platform. Consent was signed through the program's registration process. Below is a chart providing age, upcoming grade level, and reported ethnicity. Pseudonym names were given to the students to maintain confidentiality in their identities. Table 8 shows the demographics of the study students.

**Table 8**

*Study Participants' Demographics*

| Label | Age | Gender | Upcoming Grade Level | Race |
|---|---|---|---|---|
| Lennette | 10 | Female | 6th Grade | African American |
| Kori | 12 | Female | 7th Grade | African American - Biracial |
| Madison | 12 | Female | 7th Grade | African American |
| Moni | 11 | Female | 6th Grade | African American |
| Aydan | 11 | Male | 6th Grade | African American |
| Mason | 12 | Male | 6th Grade | African American |
| John | 13 | Male | 8th Grade | African American |
| Roger | 12 | Male | 7th Grade | African American |

The eight students in the study are all of African American descent. Lennette was a rising 6th grader from Georgia who self-identified as African American. Kori was a rising 7$^{th}$ grader who lived on the west coast and self-identified as having African American descent. Madison was also a rising 7$^{th}$ grader from a major metropolitan area. Moni was a rising 6$^{th}$ grader who self-identified as African American. Aydan was also a rising 6$^{th}$ grader from a major metropolitan area. Mason was arising 6t grader who identified as African American. John was the older of the group. He was a rising 8$^{th}$ grader. The last participant, Roger, was a rising 7$^{th}$ grade who self-identified as African American.

***Role of the Researcher***

I am an African American educator with experience teaching middle and high school students in economically challenged schools. My seven years as a classroom teacher were spent with minority students who faced many challenges. As a middle school teacher, I taught sixth and eighth-grade mathematics. As a high school teacher, I taught students Algebra 1, Algebra 2, and Geometry. I had many successes and challenges as a classroom teacher. One success I encountered was the ability to build a rapport with my students. As a classroom teacher, I successfully motivated students to engage in and pursue challenging tasks that included open-ended investigations. With success comes challenges. One major challenge I encountered did not have enough time to implement more projects for the students to complete. Another challenge I experienced was helping students who migrated often. Some students would be gone for months at a time and would come back with missed instructional opportunities.

Additionally, I have worked as a mathematics coach, where I assisted teachers in the classroom in the subject of mathematics and science. As a classroom teacher, I tried many strategies to engage my students in mathematics, which prompted my transition to the math coach position after district personnel observed my implementation of problem-based learning activities. My interest in problem-based learning occurred when I sought strategies to motivate students who disliked mathematics. As a mathematics coach, I shared strategies such as problem-based learning to help engage and motivate students in the classrooms across the district. I would hold professional learning sessions facilitating the use of problem-based learning in the classroom. At first, it took a minute to receive teacher buy-in, but eventually, teachers started implementing open-ended problems and investigations.

My professional development sessions triggered another promotion, where I was promoted to the district mathematics specialist position. My duties included creating benchmark assessments, monitoring the assessment data, and creating enrichment plans from the data. Additionally, I created and modified the curriculum and modeled lessons for teachers across the district. Lastly, I hosted various professional development sessions for teachers to improve student outcomes in mathematics.

After leaving public education, I worked as a consultant in the private education sector. As a mathematics consultant, I modeled standard-based lessons and assisted teachers with planning and implementing the lessons. Also, I trained teachers and district personnel on lesson strategies and supplemental mathematics software usage.

During the last years of my doctorate program, I supervised pre-service teachers. During my tenure as a university supervisor, I helped the teachers create and plan classroom implementation lessons.

My interest in culturally relevant teaching began when I had the pleasure of teaching a repeaters Algebra 1 class. The students in this class had failed Algebra more than once and needed the class to graduate. I started researching ways to motivate the students to learn the content. I created scenarios involving sports, cars, shopping, and money through trial and error. The students started responding to the scenarios. The following year, I attended conferences and visited sessions focused on including culture in mathematics instruction. Also, at the conferences, I learned various technologies such as Desmos to use in the classroom.

During my doctoral journey, I registered for classes such as Ethnomathematics, culturally relevant teaching, and Teaching for Social Justice. After diving into the research literature about culturally relevant pedagogy. I have presented at several conferences nationally. The audience of the conferences were teachers, mathematics coaches, and mathematics academic educators.

My experiences are important as a researcher because I learned strategies and tools to design and implement lessons in any setting. My educational background includes instructional design and development, where I have the knowledge and experience to consider the learner as I create learning activities. As the researcher, I designed the lessons taught in the study. I also facilitated two weeks of instruction to middle school students for the four-week camp. The students met daily for one hour to receive instruction using the Culturally Relevant Cognitively Demanding task.

**Source of Data**

The data used in this study was secondary data collected during the IAMSTEM summer camp during the summer of 2020. The data consisted of videotapes of lessons implemented during the summer camp. The classes were divided by gender. The day-to-day lessons for each week are outlined in table 9 for the Graffiti task and table 10 for the Covid 19 task.

**Table 9**

*Lessons for Graffiti Task*

| **Day** | **Lesson Activity** |
|---|---|
| **1** | Students previewed a video to discuss graffiti as art or vandalism. Next, Students completed a Padlet activity to discuss whether graffiti was art or vandalism. Finally, the students completed a WebQuest (see appendix E), where students visited different sites and answered questions. In WebQuest, students identified different math shapes in the mural |
| **2** | Students completed a getting to know you Desmos scavenger hunt (see appendix I). Next, students explored creating equations in the Desmos activity (see appendix F). Students were given a picture where they created and transformed equation to recreate the picture |
| **3** | Students shared basic equations (see appendix G) and started to create pictures in Desmos |

| Day | Lesson Activity |
|---|---|
| **4** | Students continued to work on their pictures in Desmos. Students that were having difficulties finding pictures were given a choice board of possible murals |
| **5** | Students continued to work on their pictures in Desmos. Students that were finished presented their art produced in Desmos. |

In the lesson from table 9, we used the digital tool Padlet on the first day. Padlet is a free digital tool where teachers and students can post notes for everyone to see (Sese, 2022). Also, on that day, we used WebQuest. A WebQuest is an inquiry-based digital tool where students explore and evaluate information (WebQuest Explanation, 2004).

***Table 10***

**Table 10**

*Lessons for Covid-19 Task*

| Day | Lesson Activity |
|---|---|
| **1** | Students first completed a KWL about Covid-19 (see appendix H), where they highlighted what they knew about Covid-19, What they wanted to know about Covid-19, and what they learned about Covid-19. Students were presented with a video discussing the disparities in health care with Covid-19 to complete the learned column |
| **2** | Students completed a Desmos activity (see appendix H) that explored graphing using scatter plots. The activity investigated rates and interpreting data. |
| **3** | Students searched for their information and started to create their infographics |
| **4** | Students continued to create their infographics |
| **5** | Students shared their Covid-19 infographics and discussed the overall projects for the elective mathematics class. |

Table 10 displays the lessons for the Covid-19 task. Students used a strategy known as KWL to communicate what they know, what they want to know, and what they learned about Covid-19 from the video. A KWL is a structured graphic organizer that activates prior knowledge, provides a purpose for gathering information, and summarizes information (KWL Comprehension Strategy, N.D).

**Data**

Yin (2014) provided a list of potential sources of evidence for a case study design: documentation, archival records, observations, and physical artifacts. This study used video-recorded secondary data of the lessons presented, electronic copies of student artifacts, and screenshots of student artifacts from the I AM STEM 2020 summer program.

The video recordings showed lessons of students engaging in culturally relevant cognitively demanding tasks facilitated by me, the researcher. The lessons were implemented over two weeks with two groups of middle school students for an hour each day. The groups were gender-based. The literature surrounding the benefits of gender-based instruction in mathematics shows minimum differences in achievement when compared to coeducational classes in a school (Brown & Ronau,2012; Pahlke, Hyde, & Allison, 2014). Because there are minimal differences in outcomes, gender-based instruction was not explored in this study.

Another source of data was video-based observations. Observations provide an avenue to collect information and witness how a phenomenon may unfold (Merriam & Tisdell, 2016). Video recordings that can be used for observations provide a record of behaviors and communications that happened in real-time (Cohen et al., 2018). Additionally, the video recordings that can be used in observations maintain a chronological sequence of events that may be viewed several times (Cohen et al., 2018).

Since this case study was completed in a virtual setting, the observed video recordings were appropriate to examine the students' use of culturally relevant cognitively demanding mathematical tasks. The video observations provided" invaluable aids for understanding the actual use" of the CRCD tasks (Yin, 2014, p114). Furthermore, the video recordings of the classroom lessons allowed the capture of virtual behaviors of the students as they engaged in the mathematical task.

**Data Analysis**

Yin (2014) stated that four principles should be present to analyze a case study. First, the researcher should attend to all evidence (Yin, 2014). Transcripts from the video-recorded classes were used to investigate the experiences of African American students engaged in culturally relevant mathematical, cognitively demanding tasks. The videos were transcribed using Otter.ai, an online transcription software. The software, Otter.ai, allowed speeding up the process of transcription. Included in the video records were student interactions from the chat box. Otter.ai is a paid online transcription software. Other evidence included student artifacts submitted to the camp and screenshots of student work from the video recordings.

Second, the case study should address all interpretations (Yin, 2014). Transcribed recordings were put into smaller units to determine what was relevant information for this study. The relevant information was determined by examining whether it supported the description of mathematical experiences, the NCTM process standards, and the CRCD mathematical tasks framework. Mathematical experiences, as it relates to Hatfield (1991) and NCTM (2014), focus on discourse, problem solving, cultural connections, mathematical language, positive emotional states of being, and inquiry (questions).

Third, the analysis should address the case (Yin, 2014). I examined African American students engaged in culturally relevant cognitively demanding mathematical tasks in an online STEM camp in this study. The data unit is limited to the African American students in this camp, as observed in the video recordings. Additionally, the revised transcripts only included the students in this case study.

Fourth, the researcher's expert knowledge should be infused into the case study (Yin, 2014). In this study, I facilitated the lessons using strategies gained through years of classroom teaching, mathematical coaching, and professional development facilitation. My experience in mathematics provided insight into the categories that support mathematical experiences in the classroom. Furthermore, my experience as an educator assisted in building a rapport with the students. According to Barley and Bath (2014), it is important to establish relationships and trust when collecting data and accessing the field. Rapport and relationships will influence the research design, which leads to lower attrition (Cohen et al., 2018).

The data analyzed for this research study were video recordings of the lessons recorded in Zoom. Two processes were used during the data analysis process. The first process includes analyzing the field notes captured from the video observation of the lessons. The field notes included notations of the students' behaviors and conversations during the lessons.

The second process used content analysis to identify the NCTM's process standards and keywords connected to the culturally relevant cognitively demanding mathematical task framework evident in the study. Content analysis involves identifying and summarizing predetermined words or phrases (Cohen et al., 2018). The content analysis process aims to "deliberately move from the original text to analysis of the information" (Cohen et al., 2018. p.674). Content analysis can include any document, including transcriptions, to reduce texts through pre-existing categories and theories (Cohen et al., 2018).

The data were analyzed using the six stages of content analysis (Cohen et al., 2018, p. 675). The six steps are as follows:

1. Choosing an appropriate sample of data
2. Breaking down the text into smaller units of analysis
3. Developing categories for analyzing data
4. Coding the units using the categories
5. Conducting frequency counts of the occurrence of the units
6. Analyzing the text and establishing the relationships

Step one entails defining the sample of people who will be investigated. Step two encompasses extracting data that represents your data sample. Step three is to create the categories. Pre-existing categories were used. Step four is to code the data using the categories. Step five is counting the occurrences of the codes to make decisions about importance. The last step is to analyze the data and summarize the information.

**Validity and Reliability**

Cohen et al. (2018) stated that validity in qualitative research has several principles. The first principle is that the "researcher rather than a research tool- is the key instrument of the research" (Cohen et al., 2018, p.247). In other words, the researcher is active in the research process. In this research study, I served as the facilitator of the lessons implemented in the study. I planned the lessons and provided instruction to the students in the summer camp. After completing the summer camp, administrators recorded the lessons and observed the researcher implementing the lessons to ensure further validity. I observed the videos of the lessons and transcribed the participant's engagement in the lessons.

The second principle that supports validity in the research is that 'data are socially situated, and socially and culturally saturated" (Cohen et al., 2018, p.247). The data collected in this research study provided instruction in a summer camp setting where students voluntarily engaged in the camp. Students had the opportunity to interact virtually with all students in different classes. Additionally, the students could engage in culturally relevant activities about art and covid-19.

The third principle that supports validity in this research study is that "data are presented in terms of the respondent rather than the researcher" (Cohen et al., 2018, p.247). The data in this study consists of transcribed conversations of the students during the class session. I had no control over the recordings. In order to preserve the integrity of the transcriptions, I used computerized software to transcribe the recordings initially, printed the transcribing, and manually aligned the transcriptions to the video. Additionally, student work data was collected as another source of data.

Reliability in qualitative research refers to the "a fit between what researchers record as data and what occurs in the natural setting" (Cohen et al., 2018, p.247). Reliability in this study is achieved because the camp administrator recorded the summer camp sessions. I could not control the recordings, only access the session recording. The lessons were captured in the virtual setting. Additionally, the observation would provide information that would not change due to observing recordings.

**Ethics and Confidentiality**

Bogdan and Bilken (2007) declared that ethics "are the principles of right and wrong that a particular group accepts at a particular time (p.48). Ethical considerations require that subjects are protected from harm, students consent to participate in the study, students' information remains private and confidential, and the researcher provides truthful reporting and analysis (Bogdan & Bilken, 2007; Merriam & Tisdell, 2016; Cohen et al., 2018).

The data used in this study was secondary data where students voluntarily participated in a summer intervention program. Parents of the students signed a media consent providing permission to use the video recordings. Additionally, parents consented to the usage of archival data for research. Since the data in this research study is secondary, there was no harm to students.

Confidentiality was retained by password-protecting the videos. Additionally, I used pseudonyms instead of identifiable names during the video transcription process. Pseudonyms protect the real identity of the students in the study.

**Limitations**

This study had several limitations. Due to the pandemic, face-to-face interactions were not held. Even though Zoom provided a platform to deliver instruction, it hindered the human interaction that may have occurred in a face-to-face classroom. The African American students had the opportunity to engage in the mathematical task; however, sometimes, technical issues did not allow for the students to share their screens or to turn on their cameras.

Another limitation was time. The summer camp lasted for four weeks, and students followed a schedule. Sometimes due to uncontrollable factors, students did not have the entire class period to complete the work supporting the tasks. Additionally, the length of the summer camp truncated some investigational time with the culturally relevant cognitive demanding mathematical tasks.

Furthermore, certain behaviors were not observable because the students only appeared on the screen. Observations in a normal classroom allow the observer to witness body language and include other behaviors in the field notes. However, the virtual environment limited observing these behaviors since students had the power to turn their cameras on or off.

**Summary**

In this chapter, I started with a description of qualitative research. Qualitative research allows for the research to be taken in its natural state, allows the researcher to analyze data, and asserts that the theoretical framework guides the study. Next, I provided a rationale for the selected case study as the methodology. This case study was bounded by the participation in the CRCD mathematical tasks and by the schedule presented at the camp. Eight African American students were the focus of the study.

This study investigated the mathematical experiences of African American students' engagement in culturally relevant cognitively demanding mathematical tasks. The culturally relevant cognitively demanding mathematical tasks were unpacked to see if the task met the qualifying criteria. The two selected tasks were categorized as high-level cognitively demanding.

The research context was explained in this chapter. The research used secondary data of video recordings and student artifacts to investigate the experiences, where video recordings captured the virtual lessons facilitated by me, the researcher. The synchronous learning environment simulated a face-to-face classroom allowing for discussions and whole group interactions (Shamir-Inbal & Blau, 2021).

Next, in this chapter, I provided a synopsis of my experience as an educator. I described my interest in culturally relevant activities and my experience teaching students, preparing teachers, and creating curricula. My years as a consultant also provided me with experiences across different cultural backgrounds.

Additionally, in this chapter, the data analysis procedures were explained. I used content analysis to analyze the data. The process of content analysis was selected since content analysis allows for the use of pre-existing themes and categories (Cohen et al., 2018). In the final sections of this chapter, I discussed ethics and confidentiality and the study's limitations.

# 4 DATA ANALYSIS AND RESULTS

Merriam (2016) suggested the "phase of data analysis in a case study, all information about the case be brought together" (p.233). This study investigated African American students' experiences engaging in culturally relevant cognitively demanding mathematical tasks. This study captured the experiences of African American students enrolled in the I AM STEM summer camp that focused on science, technology, engineering, and mathematics (STEM) using qualitative research. This study centered around the following research questions:

1. In what ways do we describe the mathematical experiences of African American students while engaging in CRCD mathematical tasks?
2. In what ways do the National Council of Teachers of Mathematics process standards become evident in the mathematical experiences of African American students while engaging in culturally relevant cognitively demanding tasks?

This chapter presents the data analysis and findings of the mathematical experiences of the students engaged in the culturally relevant cognitively demanding mathematical tasks during the two-week implementation of the lessons. The results provide examples of applying the features of the CRCD Mathematics tasks framework and examples of the observed NCTM process standards.

## Data Analysis

Content analysis was used as the approach in data analysis. Content analysis allows using pre-existing categories to organize and summarize data (Cohen et al., 2018). Three iterations of content analysis were applied using pre-existing categories. The first set of pre-existing categories were the observable actions of the students. These pre-existing categories are asking questions, answering questions, sharing information, and completion of tasks. The second set of pre-existing categories relates to the NCTM process standards. The pre-existing codes are problem solving, reasoning, communication, connections, and representation.

The first iteration of the data analysis process was centered around answering the research question about the mathematical experiences of students engaging in culturally relevant cognitively demanding mathematical tasks. Field notes from the videos were analyzed to capture and share the observed mathematical experiences. The second iteration of the data analysis focused on the features of culturally relevant cognitively demanding tasks. The third iteration targeted the second research question investigating the NCTM process standards that were evident as the students engaged in the lessons.

I observed the video recordings for the first iterations to identify content concepts that may be used in the analysis process. I then observed the video recordings for a second time, observing and taking notes on the students' actions.

Once the recordings were reviewed, I transcribed the videos to create the appropriate sample using the computerized transcription program Otter.ai. Computerized software can be used to export data from one format to another format. The video recordings were transferred into text for data analysis using content analysis. During the transcription of the videos, pseudonyms were used for all student references. In this qualitative research study, secondary data was used to analyze data. The secondary data consisted of videos that were transcribed using transcription software. The video recording included transcriptions of all students' schedules for the middle school math elective on the designated days. Choosing the appropriate information to include consideration of who was involved, capturing the video records, and the accuracy of the text are part of the content analysis process (Cohen et al., 2018). The secondary data were recordings of online classes via ZOOM, a video conferencing software that enables the use of features that encourage participation. Facilitators recorded the classes as I led the lessons. I later transcribed the recordings, printed the transcripts, and viewed the videos with the transcriptions to confirm accuracy.

**Mathematical Experiences of African American Students**

Mathematical experiences are created when students engage in meaningful tasks connected to their lives (NCTM, 2014). Students in this study engaged in different activities that supported the creation of a Graffiti picture using the online Desmos graphing calculator and investigated data related to the Covid-19 pandemic. Desmos is a free web-based graphing calculator.

While tallying the observations, I focused on the student's experiences. The experiences I examined were questions that were answered, information that was shared, questions that were asked, and whether the students completed the assignments. I tallied instances from the field notes that fit the above descriptions.

Table 11 displays an example of an excerpt from the observation tally for the students in the study. The students, on day one, engaged in several activities. First, the students viewed a video about graffiti. Next, the students completed an activity discussing whether graffiti was an art of vandalism. Students then completed a WebQuest where they identified math shapes in a graffiti mural. The lesson closed with students examining a different graffiti mural, again identifying the math in the mural.

**Table 11**

*Example of Excerpt of Video Observation Coding*

| Students | Excerpt | Observed Experiences |
|---|---|---|
| Lennette | Lennette completed the Padlet and the Webquest. | Completed Task |
| | Lennette thought that Graffiti was considered an art "because others admire it." | Answered Question |
| | Lennette shared the mathematics concepts from the Webquest. She stated the artist had to do some measuring and scaling to know if they had enough paint for the graffiti picture | Shared information |
| Kori | Kori completed the Padlet and the Webquest. | Completed Task |
| | Kori answered about graffiti being art. She stated that graffiti could be both art and vandalism. It depends on the content | Answered Question |
| | Kori shared information about the mathematical content of the graffiti murals. She viewed scaling as drawing a blueprint on paper before placing the picture on the building. | Shared information |
| Madison | Madison completed the Padlet and the Webquest. | Completed Task |
| | Madison thought graffiti was risky art when asked whether she thought graffiti was art or vandalism. | Answered questions |
| Moni | Moni completed the Padlet and the Webquest. | Completed Task |
| | Moni's response to whether graffiti is art or vandalism was "anything that is made by your own hands and is creative is art." | Answered Question |
| | Moni stated," I learned that graffiti artists use area and geometry to determine like the wall math," She was sharing what math is present in graffiti. | Shared information |
| Aydan | Aydan completed the Padlet and the WebQuest | Completed Task |
| | Aydan answered the question about whether graffiti was art or vandalism. He proposed that graffiti artists purchase the space to place their art. | Answered Questions |
| Mason | Mason completed the Padlet and the WebQuest | Completed Task |

| Students | Excerpt | Observed Experiences |
|---|---|---|
| | Mason entered the mathematical shapes he observed from the graffiti picture in the chat. | Shared Information |
| John | John completed the Padlet and the WebQuest | Completed Task |
| Roger | Roger completed the Padlet and the WebQuest | Completed Task |

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Table 11 exhibits Lennette, Kori, Moni, and Madison's experiences from the observations for day 1. All eight of the students completed the activities on day one. Likewise, four of the eight students answered whether graffiti is art or vandalism. Four of the eight students shared information during the first day of the class.

The daily examples from the observations will be given next. The descriptions will provide examples of the mathematical experiences for students. The examples are separated by tasks.

***Graffiti Task.***

On day one of the lessons for the Graffiti tasks, the lesson opened with students watching a video about graffiti as art or vandalism; next, they completed a Padlet where they shared their thoughts on whether graffiti is considered art or vandalism.

Aydan, Lennette, Kori, Madison, and Moni contributed to the Padlet, where they shared their thoughts about whether graffiti was art or not based on the video shown. Mason, John, and Roger did not contribute to the Padlet.

After the Padlet activity, students completed a WebQuest (Appendix E) where they answered questions about Graffiti and identified mathematical concepts from a Graffiti picture. All students submitted answers to WebQuest, completed the activity, and answered questions in the activity. When it was time to share the activity, not all the students shared. Aydan, Lennette, Kori, Madison, and Moni shared their thoughts about graffiti. Aydan went a step further and shared a personal encounter with graffiti. Aydan shared, “I think it really shows culture. And there are other things, especially with African “Americans, Asian Americans, and Hispanic Americans” From this excerpt, Aydan was able to recall a visit that he had to a major city and remembered the graffiti mural

As a closing, the students were shown a Graffiti mural prevalent in a major city (see Appendix J). The students' responses included mathematical terms that were visible in the mural.

On day two of the lesson for the Graffiti tasks, the students explored equations using Desmos (see Appendix F). The students completed a pre-made activity that assisted with equations and boundaries. Roger and John started the activity but did not finish due to time. Lennette completed the discovery activity. She asked questions about the boundaries and how to stop the lines. Lennette also asked about how to move the line up and down. She was discovering the concept of transformations. Kori also was able to discover the concept of transformations of lines. She was moving the line to make it align with the room.

Day three was the first day the students were able to start working on recreating their images using Desmos, the actual tasks. The students received a lesson about basic equations and were given the parent equations they may have needed to create their pictures. The lesson concluded with the students recreating a sample picture using the parent equations (Appendix H). All eight of the students attempted to complete the sample graffiti task.

Day four and five, students worked independently to complete the task of creating equations to recreate their pictures. Students shared their screens when they needed assistance and asked for help when they could not figure out an equation. The observed behaviors from the video for days four and five included students asking questions for clarification and students working on the final task. Kori asked whether the brackets were correct in the equation. “She asked a question to get clarification on an equation.

***Covid 19 Task.***

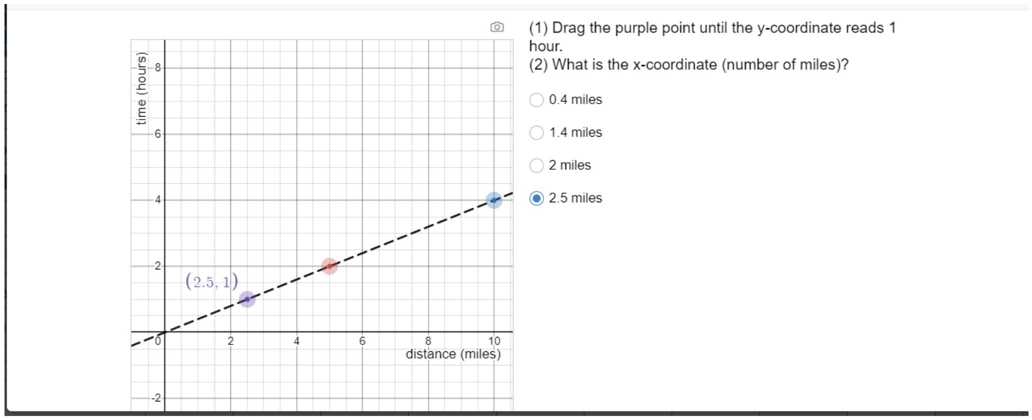
On day one of the lessons for the Covid 19 task, the lesson opened with students completing the Know of a KWL chart. Students shared what they knew already about the virus. Students shared information during this activity and asked questions. For example, Mason stated, “The bad thing about COVID-19 is we stay inside. The good thing is we get to go online with friends and teachers. The bad thing is we have to stay six feet apart; the good thing we can FaceTime “.

John shared that “It is a deadly pandemic.” The students had some knowledge about the pandemic and could share facts instead of myths and misconceptions. Next, the students shared what they wanted to know and learned after watching a video about Covid 19 and the disparities amongst African American people. The students asked questions and shared information after completing the KWL. Aydan asked, “why can't we have the same medical capability as others?” Roger also wanted to know, “Why can't there be more black doctors?” The questions asked by the students indicated the realization of healthcare disparities.

Day two of the lesson for the Covid 19 task continued with exploring graphing and interpreting data using a Desmos activity (Appendix H). This activity required students to read the graph and predict the rate of change for the graph. All of the students completed the task Figure 3 is a screenshot of part of Moni’s activity.

**Figure 3**

*Sample of Moni's Work*




The different points in the figure display the exploration to find the x coordinate for the line. The points on the graph were movable.

Also, on Day 2, students shared what they noticed about the activity. The activity involved using the application of Desmos, the online graphing calculator. Roger discovered that aspect of the slider and noticed the correlation between moving the slider and distance. A slider is a tool within Desmos that allow students to explore different coordinates while seeing the effect of increasing or decreasing values.

Day three and four, students researched information about the pandemic and started creating their infographics. Students shared information about credible websites to find information and shared the facts that they found. For example, Mason stated, "By the way, if you want to find real facts, then you can find the website says.gov. That means it is from the government." Mason was sharing a strategy to find credible sources for information. Additionally, students shared their conclusions after researching facts about Covid-19 and the Pandemic. Aydan concluded, "Oh, so I was trying to show the store opening so people could know when stores are open and what the requirements are. If I said Target Walmart and another store, I would have times where they will be open."   Madison shared her problem with locating data. Madison noted,

> "So, I am trying to figure out how to find the number of deaths. And I mean many cases for Black African Americans or people of color. So, do you research it? Because they give me percentages, percentages, and not the total numbers? So do I say that it is 16% of almost "

Kori shared what she did to assist Madison with her issue of having data in a specific format. Kori shared, "I just finished converting the numbers to percentages, and then I just typed them in. The information was fascinating."

Day five was set aside for students to share their final products and to reflect on the camp. Roger, John, Lennette, Kori, and Madison shared their infographics and discussed their findings. Lennette reported,

> "Okay, so this is my project. I am explaining why people of color are getting hit harder with COVID-19. 60% of COVID-19 cases and deaths are people of color. According to the CDC, more than 3100 researchers looked at COVID-19 deaths in late January in mid-April and found a greater number of Black counties. So how can we decrease the number? They can avoid people working, get better income and jobs, try to get a good education by listening school so that later in life, they can get a good job. One way we can help underprivileged people is to have more black and Latino-owned businesses so that they can treat them right and help others and provide supplies for them. The surgeon general does not want to mandate masks because of racism or discrimination."

Her findings included discussing discrimination and ways the underprivileged can receive assistance.

After the presentations, Lennette, Kori, Madison, and Moni shared what they learned during the two-week course. Kori reported, “So I always like playing with calculators. I also like playing with graphing calculators. Now I like playing with graphing calculators even more because I know how to use them better.” Kori had never used a graphing calculator before the lessons; Kori now knows the graphing calculator. Lennette stated, “I did not even know what Desmos was. But now I am actually kind of good at it.” Lennette expressed her comfortability with learning the tool to explore mathematics. Madison claimed, “I feel like I was supposed to learn some of this stuff later in high school. But now I know. Most of it.” Madison seemed enthusiastic about learning high school content in middle school.

**Content Analysis**

Following the tallying of mathematical experiences, I utilized the six steps for content analysis recommended by Cohen et al. (2018) to analyze the data for culturally relevant cognitively demanding task features and the NCTM process standards. The six steps are as follows:

1. Choosing an appropriate sample of data
2. Breaking down the text into smaller units of analysis
3. Developing categories for analyzing data
4. Coding the units using the categories
5. Conducting frequency counts of the occurrence of the units
6. Analyzing the text based on their relationships (Cohen et al., 2018, p. 675).

The first step of the content analysis process began with identifying the sample of data to be included. The sample of data were from the eight students that were part of the case.

The second step of breaking down the text consisted of removing irrelevant text to the research study, such as videos used in the instruction. Cohen et al. (2018) stated that the researcher should establish coding units that are “the smallest element of material that can be analyzed” (p. 676). Since this qualitative case study focuses on African American students' experiences in culturally relevant mathematical tasks, the truncated units of analysis featured African American students that actively participated in the class sessions. I removed references to facilitators, instructors, and students that were not bound by the defined case. The transcriptions were saved to another file, and text outside the case study's boundaries was deleted.

The third step required that I identify categories for analyzing data. Content analysis allows the researcher to "interrogate them (text) into summary form using pre-existing categories" (Cohen et al., 2018, p.675). Cohen et al. (2018) considered categories as the "key features of the text showing links between units of analysis" (p.677). Furthermore, it is important to note that categories can be linked to pre-existing theories related to the research (Cohen et al., 2018). Using the CRCD conceptual framework, I extracted key terms related to the features.

Hatfield (1991), Fosnot and Perry (2013), and NCTM (2014) define mathematical experiences as problem-solving inquiries that promote discourse, include multiple representations, and promote a positive emotional state for children. NCTM (2014) also states that mathematical experiences include connections to a real-world context. The following constructed codes were used to investigate evidence of the NCTM process standards:

- Problem Solving
- Reasoning
- Communication
- Representation
- Connections

Glaser and Laudel (2013) support using codes and categories that are derived from the "theoretical framework that guided data collection" (p. 15). The codes utilized

The fourth step of coding the text's content analysis protocol is using pre-determined categories. Pre-existing categories were formulated using the theoretical lens of constructivism. Categories are "conceptual elements that 'cover' or span individual examples" (Merriam &Tis-

dale, 2016, p.206). The overall purpose is to use categories or themes to answer the proposed research questions. In order to achieve this goal, first, after reviewing the data, the researcher should identify “segments” that are “responsive to the researcher's questions (Merriam & Tisdale, 2016, p.203). The segments should reveal information about the study and be interpreted (Merriam and Tisdale, 2016). The data from this study proved to be rich. The analysis yielded significant information regarding the experiences of African American students participating in culturally relevant cognitively demanding tasks. Computerized ATLAS.ti aided in the coded process once the categories were identified. ATLAS.ti is a computerized assisted data analysis program that assists with organizing, coding, searching, and collating data (Cohen et al., 2018). Since the codes have been established, the actual analysis can begin, where code and categories are assigned to the text (Cohen et al., 2018). Glaser and Laudel (2013) distinguish categorizing data as extracting meaning when the categories are theory-driven. With the aid of computerized software, the first iteration of assigning codes examined sentences that fit the categories. Using the search feature in Atla.ai, I searched for keywords that pertained to each code. Once the search was complete, I read each sentence to see if the sentence reflected the code's intention. If the sentence matched, the code was applied to the sentence. If it did not match, then the code was rejected. During the iterations of searching, synonyms were added to expand the occurrences. It was important to include synonyms to reduce significant data loss (Cohen et al., 2018). After coding each sentence from the sample data unit, the codes were assigned to the categories.

The fifth step of the content analysis protocol consists of conducting a frequency count of the categorized text. The sample transcribed text counted key categories as they pertained to the learning experiences of African American students. This content analysis step requires the researcher to tabulate the occurrence of each code. It is recommended that the researcher start with small text units to establish validity and then expand to the entire sample of data (Cohen et al., 2018). This step helps preserve coherence when analyzing data (Cohen et al., 2018).

Table 12 represents the coding regarding the NCTM process standard for the graffiti task. Recall that the five process standards are problem solving, reasoning and proofs, representation, communications, and connections.

**Table 12**

*NCTM Process Standard Coding Graffiti Task*

| Descriptive Codes | NCTM Process Standards | Total Occurrence Frequency |
|---|---|---|
| Solve, answer, figure out, acknowledge, comprehend, conclude, infer | Problem Solving | 124 |
| equations, symbols | Representation | 5 |
| discourse, talk, speak | Communication | 34 |
| family, community, culture, concepts | Connections | 22 |
| idea, think, thought, reason, ask, examine, inquire | Reasoning and Proof | 24 |
| | **Totals** | 209 |

From table 12, problem solving has the highest occurrence, and representation has the second highest occurrence. This indicates that the Graffiti task promoted student mathematical experiences where students were engaged in doing mathematics through problem solving and representation.

Table 13 represents the coding of the NCTM process standard for the Covid -19 task.

**Table 13**

*NCTM Process Standard Coding Covid 19 Task*

| Descriptive Codes | NCTM Process Standards | Total Occurrence Frequency |
|---|---|---|
| solve, answer, figure out, acknowledge, comprehend, conclude, infer | Problem Solving | 19 |
| equations, symbols | Representation | 5 |
| discourse, talk, speak | Communication | 25 |
| family, community, culture, concepts | Connections | 4 |
| idea, think, thought, reason, ask, examine, inquire | Reasoning and Proof | 53 |
| | **Totals** | 106 |

Table 13 displays the frequency of occurrences for the Covid-19 task. Reasoning and proof have the highest occurrence indicating that the Covid-19 task promoted student mathematical experiences where students were engaged in doing mathematics through reasoning and proofs. The coding of the frequencies revealed that during the implantation of each task, the five process standards were evident. I will show prominence for each standard individually to better understand each process standard. First, I start with the process standard for problem solving. Next, I will prove examples from the reasoning and proof standard. The communication standard will occur third. Following the communication standard is the representation standard. Finally, individual examples from the connection's standard will be shared.

The problem solving process standard was evident when engaged in a CRCD mathematical task. Recall that the process standard for problem solving requires students to apply different problem-solving methods (NCTM, 2000). Additionally, Norris and Schuhl (2016) suggest that

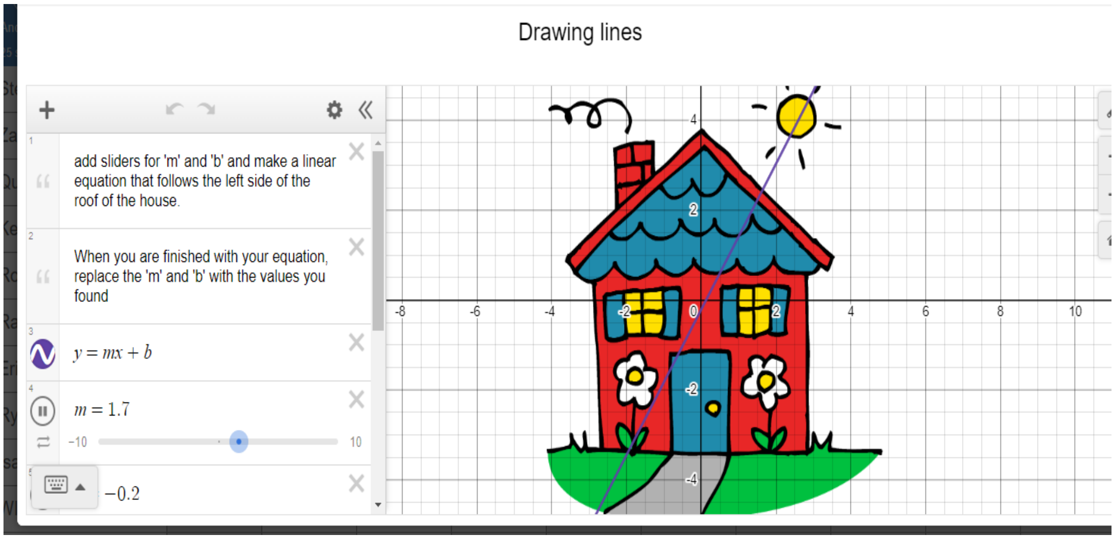
students solving problems include making changes to their strategy and evaluating the reasonableness of the solution. Lennette demonstrated using the problem solving process standard by trying different methods to create her picture. For example, Lennette
shared that during the graphing process, she was getting two different lines. This quotation demonstrates the student changing their strategy while creating equations for the Graffiti task. Another example of problem solving during the implementation of the Graffiti task of making changes to a strategy occurred when this quote was transcribed by Aydan “Okay, so I just mess around with a bunch of stuff and figure out how to make a slanted line.” The student explores equations of functions using Desmos, a web-based graphing calculator.

During the Covid-19 task implementation, Madison shared that she was trying to figure out why the statistics for African Americans were higher than others. This instance demonstrates that the student is trying to “identify the critical information in the task they need to solve the problem” (Norris & Schuh, 2016, p, 15). This instance is another example of the process standard for problem solving during the engagement of CRCD mathematical tasks.

Another instance of problem solving occurred when John was changing the equations to create the door of the picture. In Figure 4, a line is observable. John used guess and check to manipulate the equation to fit the door. Guess and check is a problem-solving strategy (Morton, 2014).

**Figure 4**

*John's Student Work*




The reasoning and proof standard involves students recognizing patterns, justifying results, and making generalizations (NCTM, 2000). Evidence of reasoning includes students looking for mathematical relationships, connecting concepts, identifying meaning, checking for reasonableness, providing explanations about concepts and context, and utilizing the context of a problem (Norris & Schuhl, 2016). For example, a student displaying the reason and proof standard may compare and contrast two methods for solving a problem, then justify why one method is advantageous over the other one.

During the WebQuest activity, Lennette demonstrated reasoning. Lennette shared the mathematics concepts from the WebQuest. She stated the artist had to measure and scale to know if they had enough paint for the graffiti picture. Based on her observation, she used the concepts of scaling and measuring to justify the amount of paint the artist would need.

Similarly, Madison displayed evidence of reasoning and proof when she concluded that graffiti artists used geometry and spatial reasoning to visualize the amount of wall space needed to paint a graffiti mural. Madison connected three-dimensional concepts to graffiti murals.

Kori imagined the use of scale drawings to create graffiti murals. Kori shared, “I might be thinking a different way from Lennette. They (artists) might have drawn out their design and said that one inch could equal one foot in real-life. They (artist) would be scaling to plan out the actual size.” This statement has several occurrences of reasoning. First, Kori used the context of the problem to think about the steps the graffiti artist would take. Next, Kori connected concepts to a real-world context. Finally, Kori acknowledged Lennette’s answer and provided a different justification for her own answer.

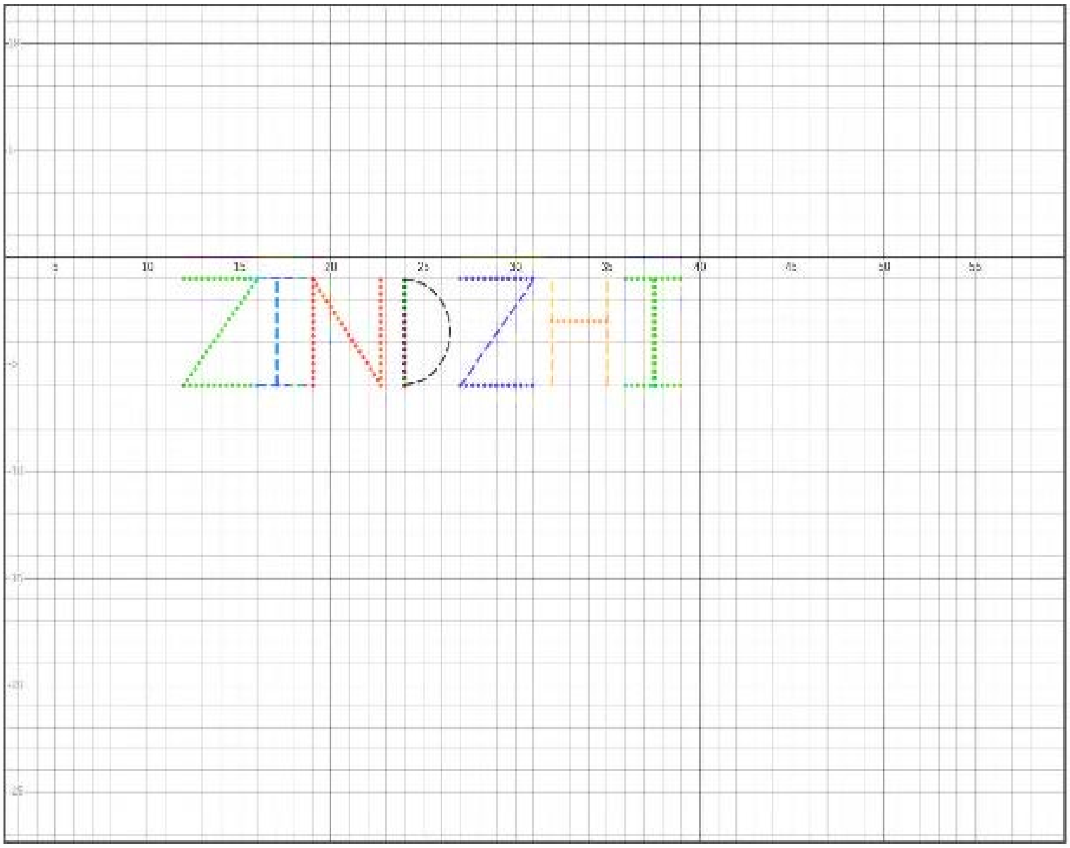
Students who engage in CRCD mathematical tasks communicate mathematics using appropriate terms and language. According to Norris and Schuhl (2016), students communicate with each other, and the teacher incorporates the following:

- Using examples to present information
- Use diagrams and visuals to share information
- Use appropriate mathematical vocabulary
- Restate information

Students presented a Graffiti picture of different equations (Appendix A) and an infographic discussing Covid-10 (Appendix B) during the two-summer camp final product. Figure 5 is an example of work turned in by Madison. The illustration uses examples to present mathematical information. For instance, equations are utilized in displaying some lettering art.

**Figure 5**

*Madison's Graffiti Project*




Students engaged in CRCD mathematical tasks demonstrated the NCTM process standard of representation. According to Norris and Schuhl (2016), evidence of students using tools to reason includes:

- Using multiple representations
- Make a connection between concepts
- Look for relationships among math values
- Use the context of the problem (p. 45)

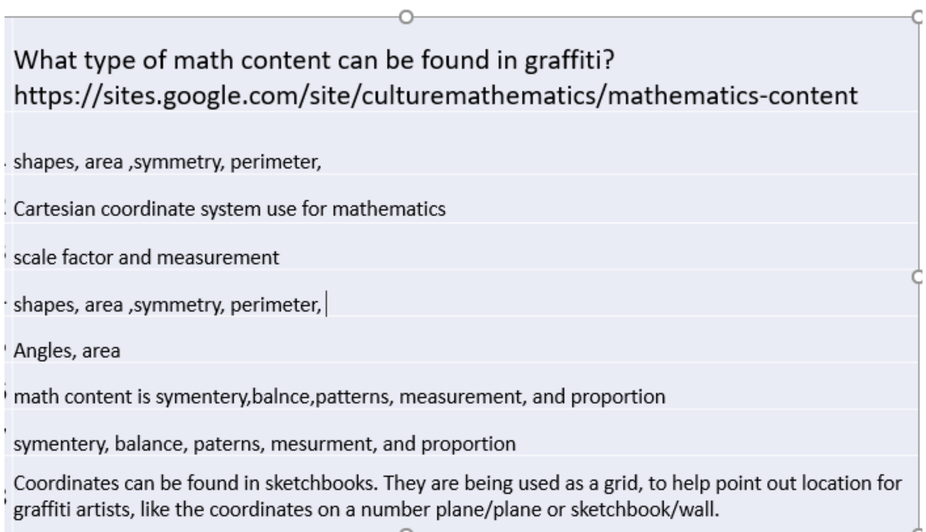
Evidence of the representation process standard is demonstrated when Kori exemplifies using tools to support thinking by making connections between concepts. For example, Kori stated:

"I agree with Lennette, but I also think that they might have viewed scaling differently. They might have drawn out their design and say (sic) one inch could equal one foot in real life. But they would just be scaling that way so then they could plan out the actual size and use a smaller size to make proportions quick (sic)

This quote from Kori mentions the concept of scaling and proportions to discuss the possible blueprint of graffiti artists before they start to create art. Another example of the students using tools to support their thinking occurred when students opened the Graffiti activity to identify mathematical shapes in a mural. Figure 6 shows WebQuest, where students connected mathematical concepts to a real-world scenario. The mathematics were advanced mathematics concepts beyond the requirements of the curriculum for middle school students.

**Figure 6**

*Math in Graffiti WebQuest*



What type of math content can be found in graffiti?
https://sites.google.com/site/culturemathematics/mathematics-content

shapes, area ,symmetry, perimeter,

Cartesian coordinate system use for mathematics

scale factor and measurement

shapes, area ,symmetry, perimeter,

Angles, area

math content is symentery,balnce,patterns, measurement, and proportion

symentery, balance, paterns, mesurment, and proportion

Coordinates can be found in sketchbooks. They are being used as a grid, to help point out location for graffiti artists, like the coordinates on a number plane/plane or sketchbook/wall.

In figure 6, several mathematical concepts were connected to murals and Graffiti.

Students also used Desmos, a web-based graphing calculator, to support their thinking. Students in this instance were displaying a high level of cognitive demand. The WebQuest required students to think about mathematics connections portrayed in art. The students witnessed the real-life applications of geometry. (Talk about cognitive demand)

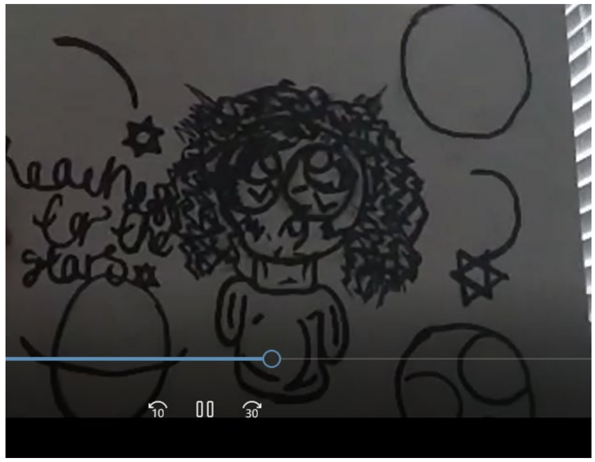
Tools in mathematics can range from pictures to manipulatives to equations. In exploring the task, students used equations as a tool to create art. Additionally, students were introduced to Desmos as a tool for creating art.

NCTM (2000, 2014) suggests that mathematics be applied to a real-world context with the process standards. Taking it a step further, Berry (2003a) recommends that this real-world experience be personal and authentic. In the analysis of the data, connections to students' lives emerged. For example, Lennette shared that her aunt created graffiti in a major city in honor of the Black Lives Matter movement. During the camp, protests occurred due to the killing of an unarmed African American, George Floyd (Sayej, 2020). The Graffiti task allowed this participant to share about her family member, making it a personalized experience.

Moreover, student M0ni shared that the Graffiti task "kind of inspired me to start my art hobby again." As stated before, the graffiti task became personalized to the students. Students had a personal choice with the selection of the tasks and the strategies used to recreate their graffiti murals. The personal choice with strategies promoted students completing tasks at high levels due to the non-algorithmic approach to completing the tasks. Additionally, students were excited to create their own pictures to import into Desmos. Figure 7 is Lennette's graffiti drawing.

**Figure 7**

*Lennette's Graffiti Drawing*



In the Covid-19 task, students discussed how Covid-19 had affected them. For example, student Lennette proclaimed that the emergency lockdown due to the spread of Covid-19 hindered normal day-to-day routines due to business closures and the mandates of social distancing. In the implementation of the Covid-19 task, students started examining data with personalized conversations evolved about the effect of the pandemic on their individual lives.

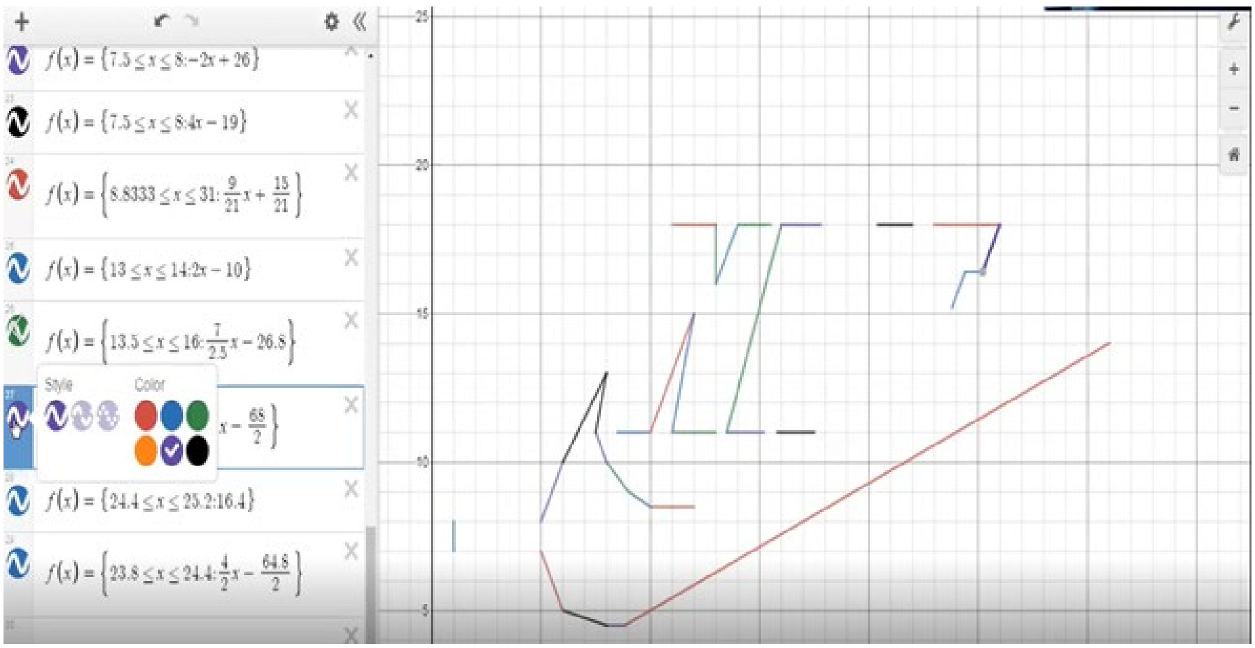
The sixth step of the content analysis protocol is to conduct the data analysis by "summarizing the inferences from the text, look for patterns, regularities, and relationships" (Cohen et al., 2018, p. 679). Cohen et al. (2018) advise researchers to look for relationships between the codes and portions of text. The examination of the text can occur in several ways and methods. For example, researchers can perform statistical regressions using the frequencies or correlate the strength of word association. (Cohen et al., 2018).

The NCTM process standards overlap during the implementation of tasks. It is common to engage more than one process standard simultaneously. After examining each process standard individually, I will explore the process standards holistically. The implementation of rigorous and challenging tasks promotes the usage of multiple process standards. First, I highlight Roger's implementation of the Graffiti task. Due to time constraints of the camp's schedule, Roger did not finish the picture before the end of the summer camp.  . After Roger, I will share Kori's work. Finally, I will share Madison's Covid 19 tasks.

Figure 8 depicts Roger's Graffiti Task.

**Figure 8**

*Roger's Graffiti Task*



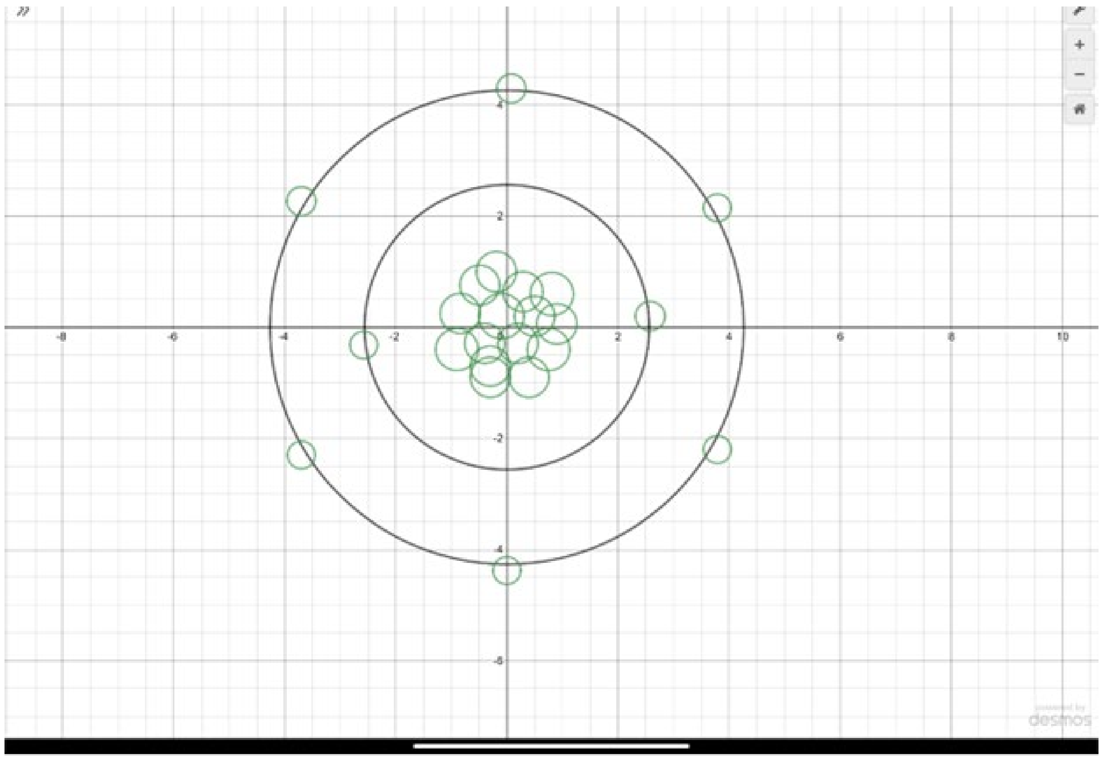
Roger's selection of the Nike symbol denoted a connection between school and his personal life. Nike is a popular brand of clothing that students wear. The clothes are immediately recognized by the display of the Nike symbol on shoes, athletic wear, and other items. Roger's selection of the Nike symbol to recreate represented his ability to see himself in the mathematics while making connections to personal likes.

In order to reproduce the Nike Symbol in the coordinate plane, as shown in Figure 8, Roger had to define the equations that would create the various lines and curves embedded in the symbol. This was a cognitively demanding task for a middle school student who had not yet taken Algebra I. The mathematics concepts used in Roger's graffiti tasks are usually introduced in advanced mathematics courses. He demonstrated knowledge of functions as shown in the graph; he used linear equations, equations of circles, and hyperbolic functions, as well as work with restrictions on the domain and range. Mathematically, Roger utilized the concepts of boundaries and set notation to graph the line segments. The connection to Roger's life included his personal choice of colors. Figure 8 display the changing of the line colors to meet his personal preference.

Evidence of the five process standards were prominent in Rogers's manipulation of equations to develop his replica of the Nike symbol in the coordinate plane. His ability to engage in **problem solving** is evident in his production. **Reasoning and proof** are evident in his ability to notice and discern patterns for graphing horizontal and vertical lines since most of the parts of the graphs are linear. Additionally, Roger proved that the equations, if entered correctly created, would recreate the graffiti picture. Roger's participation in the Graffiti task signals the usage of the **representation standard**. The **communication standard** was evident in Roger's ability to grasp an understanding of the parent functions that he used to create the equations for his graph. The **connections standard** was also evident in his ability to apply the parent function to define the equations for his graph.

**Figure 9**

*Kori's Atom Student Work*



Kori shared her picture of an atom. During the introductions, Kori expressed an interest in the field of STEM career goals. Kori's personal choice of creating an atom allowed Kori to see herself in the mathematics task. Kori's selection of the atom allowed her to see a part of herself in the activity since she wanted to be a scientist. Kori's use of color was a personal choice. Personal choice connects to one's culture (Ladson-Billings, 2014; Mathews et al., 2013).

The creation of Kori's graffiti picture in figure 10 required the basic knowledge of circles. First, Kori had to find the circle equation and define each part of the equation. Next, Kori had to explore how to graph the circle in the coordinate plane. To graph the circle, Kori had to investigate and understand the relationship between the radius and the center of the circle. After mastering graphing the standard form of the circle, the explorations of transforming the visible. Kori manipulated the circles to move them to the desired location. The graphing and transformation of circles is a high school geometry topic. Kori was a 7th grader at the time of the camp.

Kori's graffiti picture is demonstrated the **communication standard**. She was communicating an understanding of circles. Even though the equations were not appended, the picture expressed the use of the circle equations to create the graph. Furthermore, the graffiti picture demonstrated the **reasoning and proof standard**. The graph proves the use of correct circular equations to create the picture successfully. From the graph, the conclusion can be drawn that the student utilized the concepts of transformations to move the circles around, which is the representation process standard. The **problem-solving standard i**s exhibited by applying the mathematical concepts of graphing circles and transforming circles to create a picture. Kori exhibited the **connection standard** by creating a science term using mathematical equations. The picture of the atom represents the science and math relationship. Also, Kori demonstrated the representation standard in the creation of the graphs. Kori started with the basic equation of the circle and extended the knowledge to the transformation of circles.

**Figure 10**

*Madison's Covid Student Work*


Students were presented with the Covid-19 task during the second week of the camp. During the implementation of the Covid-19 task, the world was experiencing a pandemic. Schools and businesses were closed due to the high percentage of cases. African Americans were dying at an alarming rate, and health care disparities were amplified. Students had a vested interest due to African Americans' high number of deaths and transmission rates. Students saw themselves in the number of cases and deaths.

To create the Covid-19 infographic, Madison researched to gather information from reputable sources. During the data collection phase, Madison evaluated data for measures of variability. She deciphered the data for validity. Madison interpreted the meaning of the data she collected. For example, Madison determined the scaling of the charts. Madison converted percentages to quantifiable numbers for graphing and entering into tables. Inferences were made by students based on the data. Finally, she utilized the statistical information to recommend action steps to decrease the number of covid deaths and transmission cases for African Americans.

The five process standards were evident in Madison's Covid –19 task. Her ability to engage in **problem solving** is evident in the interpretation of data. **Reasoning and proof** process standards are evident in Madison's ability to decipher data for validity. The **connection** standard is noticeable in her recommendations to decrease Covid-19 cases. The **representation** standard is present in mathematical facts and information presented. The **communication** standard is demonstrated in her infographic (NCTM, 2000).

### Features of the CRCD Mathematics Framework

The CRCD Mathematics framework is a guide for selecting and implementing cognitively demanding tasks embedded in culture (Mathew et al., 2013). CRCD mathematics instruction seeks to add culture as a vital learning component (Mathew et al., 2013). In the study, the following CRCD features were visible and are discussed:

- The task is mathematically rich, high-level, cognitively demanding embedded in cultural activity. Tasks are procedures with connections or doing mathematics according to the Task Analysis Guide
- Mathematics task explicitly requires students to inquire (at times problematically) about themselves, their communities, and their world.
- Tasks ask students to engage and overcome the discontinuity and divide between school and their own lives at home and school
- The 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 makes empowered decisions about themselves, communities, and the world (p.133).

### Students engage to overcome the discontinuity and divide between school and their own lives

Students who overcome the discontinuity and divide between school and their lives can relate concepts from activities to things in their community. On the first day of the lesson implementation, students were provided background information from the video and asked to identify math terms from different graffiti murals. Students started making connections to graffiti murals they had seen in their cities. For example, Kori stated:

> "Right now, there is so much graffiti downtown in my hometown! There are ones for the BLM movement, some that say inspirational messages for COVID-19, and there are murals/graffiti thanking the first response workers."

Mani also made connections to the topic of graffiti and her community when viewing graffiti when she stated, "Downtown Dallas we have much graffiti, it is cool to see them though!" Another connection between the activity and their own lives occurred when Lennette discussed how a family member created a graffiti mural that honored the Black Lives Matter movement. Lennette stated:

"I was going to say that my aunt is a nurse, but she is also a professional artist. She did some graffiti downtown in A, in honor of the Black Lives Matter thing, and she was admitted for it."

In addition to making connections to graffiti murals in their cities, Mani shared how the task sparked her love for art again. Mani stated, "They inspired me to start my art hobby again." This statement provided evidence of connecting school to a student's life.

**Students demonstrate higher levels of cognitive demand while completing tasks embedded in culture**

Students who demonstrate high levels of cognitive demand can represent math in multiple ways, use non-algorithmic pathways to complete a task, and experience some anxiety due to unpredictable outcomes requiring some degree of self-regulation. (Stein et al., 2009). On the second day of camp, students were given the basic parent functions to explore. Once the students were comfortable with the parent functions, the students explored equations using Demos and recreated a house to become comfortable with the technology. Students exhibited a high cognitive demand by using guess and check to explore equations in Desmos. Guess and check is a non-algorithmic way to explore mathematics. According to the Task Analysis guide, a not-algorithmic approach to solving a problem is considered a high level of cognitive demand (Stein et al., 2009). Figure 11 demonstrates John changing the equation of a parabola to create the awnings on the house from the Desmos activity.

**Figure 11**

*John Investigating Equations*

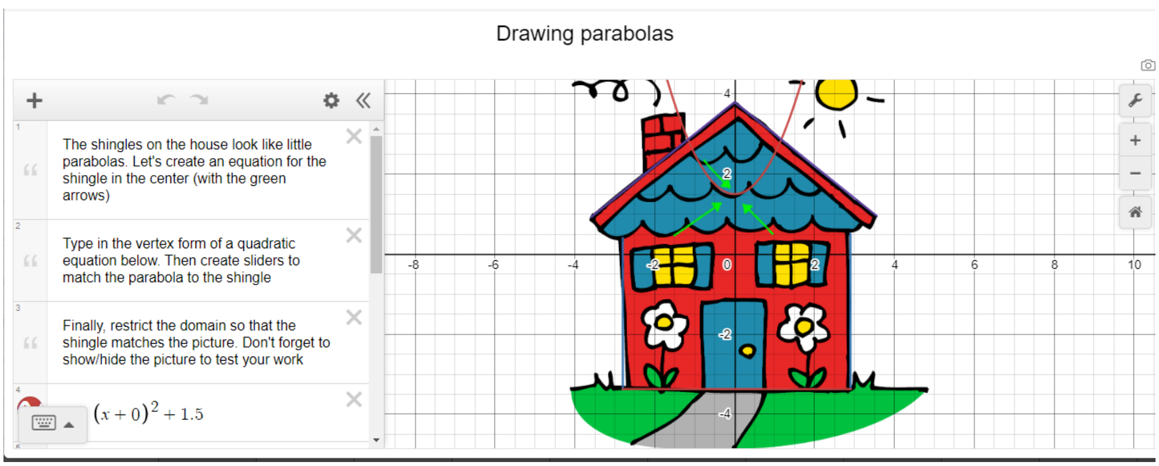
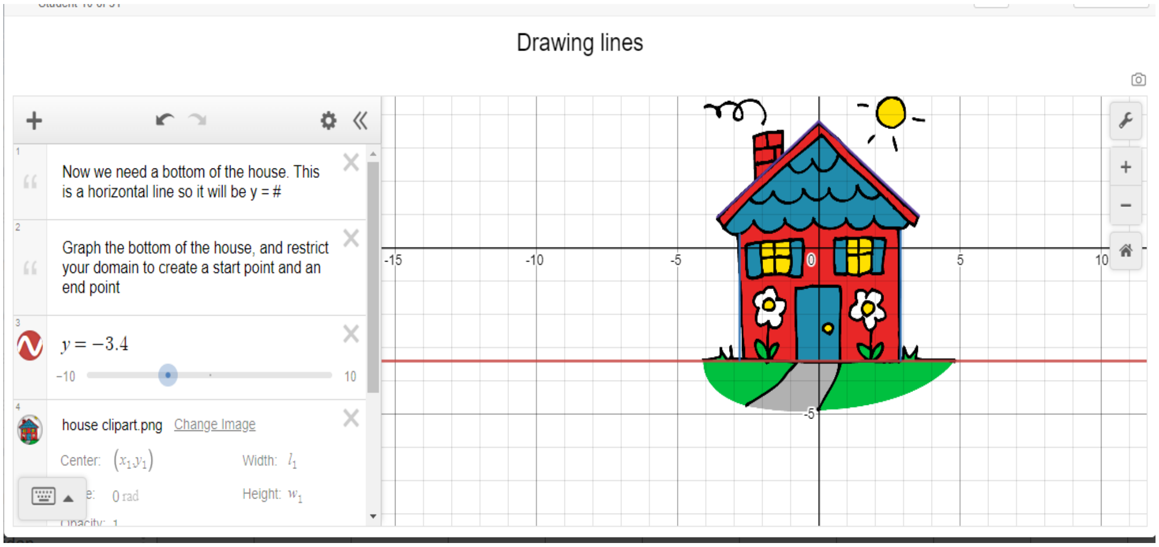



Figure 12 is another example of Moni guessing and checking to explore equations during the Desmos activity.

**Figure 12**

*Moni Investigation Equations*




M0ni is exploring the lines to recreate the house in the Demos activity.

Kori demonstrated the strategy of guessing and checking by sharing the hypothesis that if you the number in the equation to a smaller number, the line would move towards the roof of the house. She explained how she thought the y-intercept moved the line.

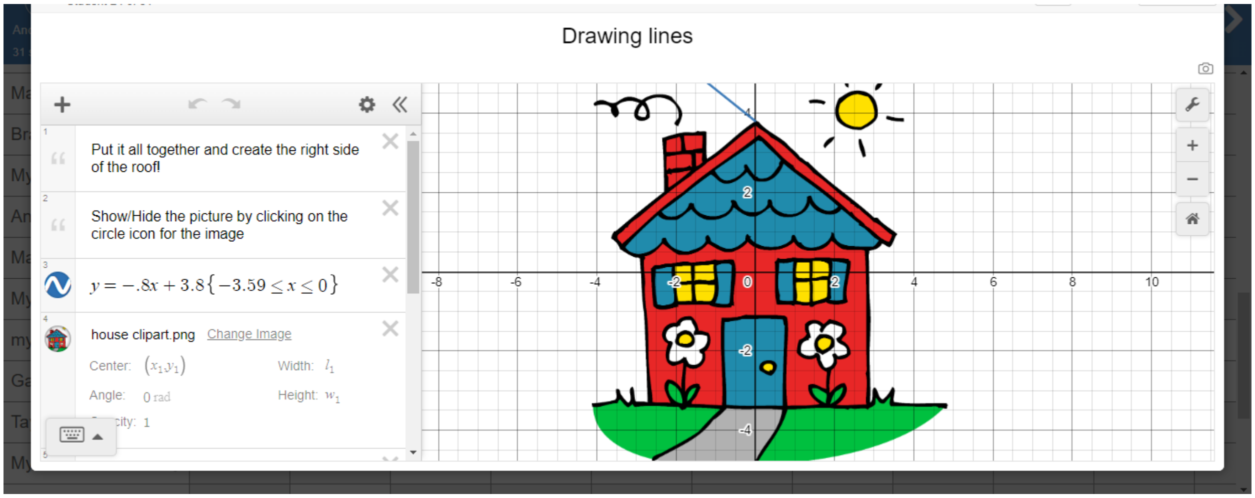
Lennette asked a question to ensure her measurements aligned with her picture while exploring the strategy guess and check. Lennette shared,

"So, the line was on the house when we did the last problem. But it had a short part. So, when we enter numbers, it does not have to go to the end? " Lennette explored how to set boundaries (domain) for her equations.

Figure 13 corresponds with the question that Lennette was asking. She was exploring the inequality that sets the domain.

**Figure 13**

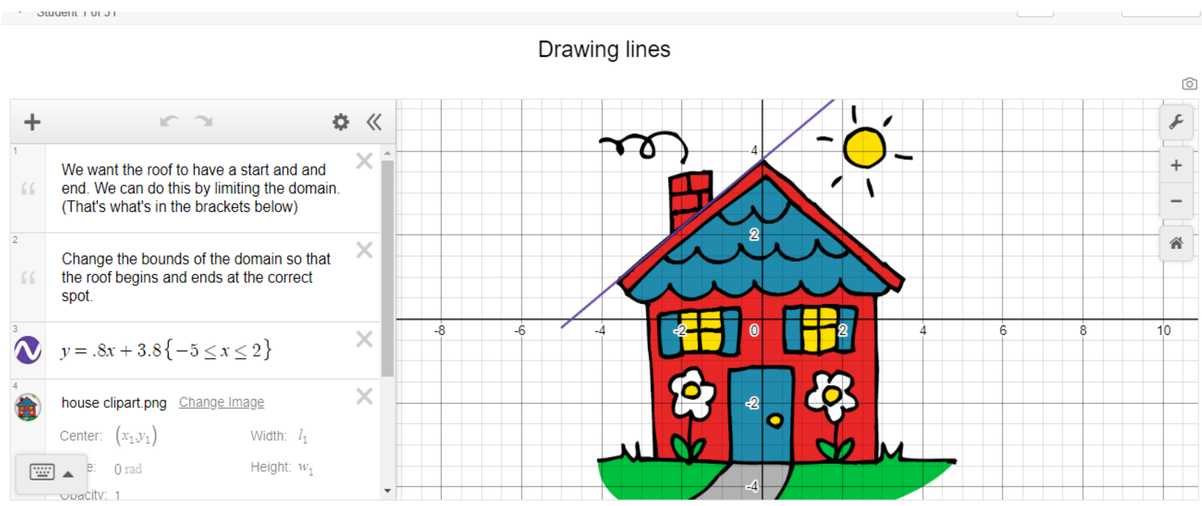
*Lennette's Desmos Work*




Similarly, Madison had the same question when trying to set the domains for her exploration. Madison asked, "‥ So, I am on the fifth one, and I am trying to figure out how to do the window in the school; we got the little alligator mouth, but they are not that, but I am trying to figure out how to put a line under." Figure 14 is a snapshot of Madison's exploration.

**Figure 14**

*Madison Desmos Activity*



During guessing and checking, Aydan inquired about the scaling for the axis. From the following statement by Aydan, he alluded to setting the scales when he graphed:

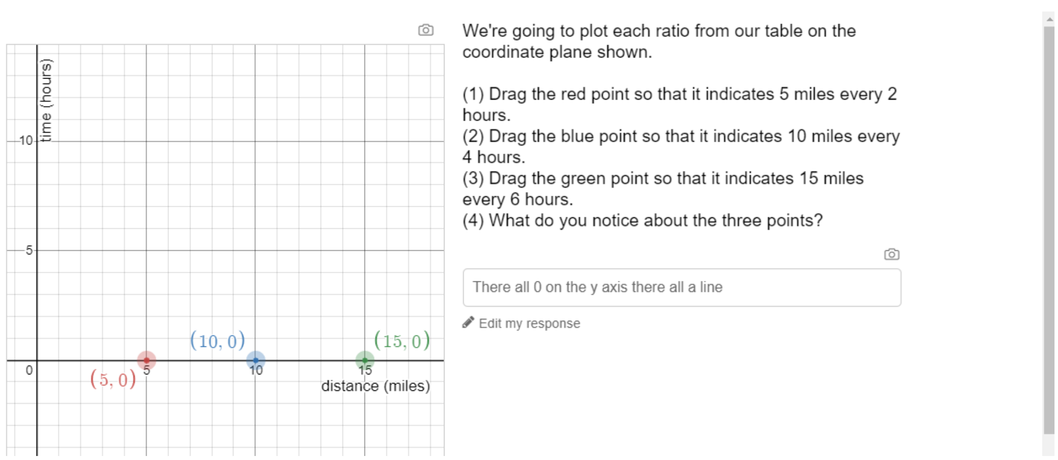
> "My question is if I was trying to get something, and in the graph, they only have a certain number, like a month. How do I get numbers in between them? They do not go in the exact position I want.,

His statement denotes higher cognitive demand because Aydan is alluding to a high school math concept and realized a mathematical connection between scaling on the axis and graphing.

Students who demonstrate a high level of cognitive demand also analyze graphs when engaging with mathematical tasks. Students engaged in a Desmos activity that demonstrated graphing and analyzing the graphs for information during day two. Mason noticed how the points moved on the graph. Mason asked, "So you know how all the other ones we were going up by twos." Figure 15 demonstrates the exploration of investigation as the points move.

**Figure 15**

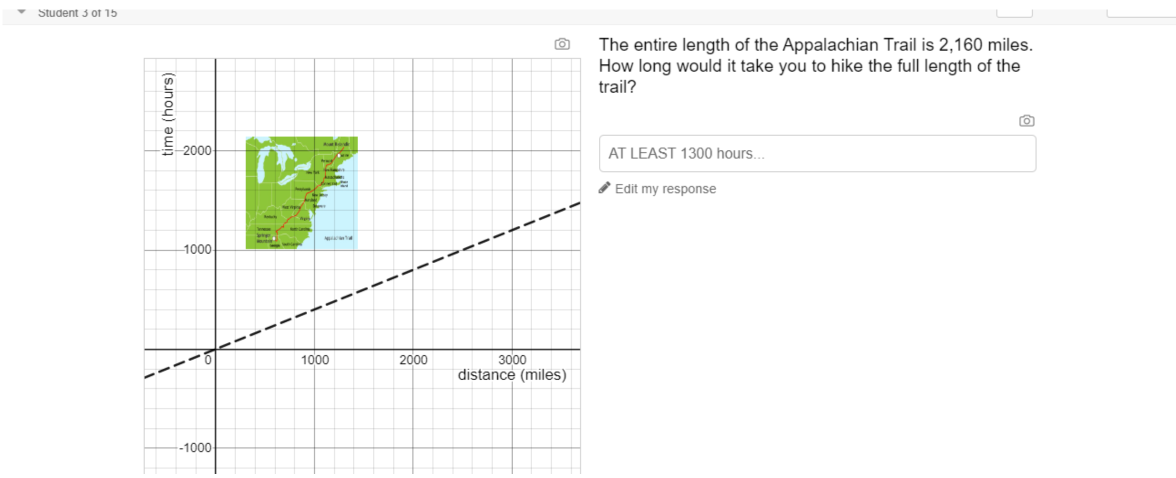
*Mason's Desmos Work*



Another example of students analyzing graphs occurred when Aydan shared an answer in the context of the graph. Aydan was answering the question presented in the Desmos Activity and comparing his answers to another student during the share-out. In figure 16, Aydan's work is displayed. The Desmos activity was a scaffolded activity designed to teach graphing and connections to rates so students can graph and interpret their Covid-19 data.

**Figure 16**

Aydan's Desmos Work




**Mathematics task explicitly requires students to inquire (at times problematically) about themselves, their communities, and their world.**

Students who inquire about themselves, their communities, and their world ask questions to understand the world in which they live. On the first day of the Graffiti and Mathematics tasks, students were presented with information that questioned the legality of graffiti in different neighborhoods. During the discussions, students wondered why graffiti murals were erected. For example, Mani wanted to know, "Why did they paint the people, are they very iconic, or did they pass away?"  Mani was trying to understand the purpose of graffiti murals in the first place.

Kori stated, “I think the graffiti can be art or vandalism. Graffiti can show emotion and is another way to share your thoughts on what may be happening. On the other hand, some graffiti can be almost vandalism, cussing, or something inappropriate. I think there is a difference between graffiti where people sign their names and graffiti where people make small murals or paintings.” Kori was trying to make sense of the difference between art and vandalism

When inquiring whether graffiti was art verse vandalism, Lennette said, “graffiti is art. Anything made by your own hands and creative is art because art can be anything along it is not offensively mean to the public. I also think sometimes graffiti can be a way to express feelings of others because most people cannot talk out their feelings with someone.” Lennette tried to understand why graffiti would be illegal since it expresses someone's feelings.

Madison, during the discussion, wanted to make graffiti legal in all circumstances. She said, “In my opinion, graffiti is a type of art in different fonts, walls, or minds. Graffiti is probably risky at this time, but maybe there is a way for you to post or draw your art on a reserved place or wall.”

Aydan thought:

> “I do think they represent colors. So, like there is a building with think Abraham Lincoln on it. The windows are like a piece of history.”

In thinking about graffiti murals, Aydan suggested that graffiti murals be reserved for famous people and people of color to express their feelings. He is questioning the graffiti murals in certain cities such as Atlanta.

Students completed the Covid-19 task during week two of the summer camp. On day one, students watched a video explaining the disparities between marginalized groups after introducing the task. During the implementation of the Covid-19 tasks, students inquired about information related to Covid-19. For example, Aydan asked, "During COVID-19, how many minorities need money for their families? So, since Coronavirus is here, they must protect themselves and provide money for their families. Okay, so why? Cannot Africa." Aydan's wonderings occur due to the implementation of the mathematical tasks.

**The task is real-world focused, requiring students to make sense of the world through mathematics.**

Students who make decisions with themselves in mind have exhibited a sense of empowerment. The Covid-19 task required the students to analyze data and provide the information they could share with the public. Even though most students did not submit their infographics, they shared their findings during the final day of week two.

Aydan used the data to recommend store opening and closing times with a mask requirement. He stated the following:

> Oh, so I was trying to show the store opening so people could know when stores are open and the requirements. If I said Target, Walmart, and another store, I would have times posted. I will put facts down about the requirements. Do we need a mask?

Aydan wanted to make sure people were safe at the pandemic's beginning. Another example of a participant using mathematics to make empowered decisions came from Kori. She was sharing her perspective on the Covid-19 pandemic. In the following statement, Kori was thinking about the lack of mandates from powerful politicians to save lives during the pandemic.

> If it was not for the president, or the person in the White House. If we had kept the recommendations from Dr. Fauci and the pandemic team, we would have been in a better place.

Madison used the data gathered to make recommendations to keep people safe, indicating empowerment. In her presentation, Madison shared:

> Okay, so this is my project. This will be why people of color are getting hit harder with COVID-19. So, 60% of COVID-19 cases and deaths are people of color. According to the CDC, more than 3100 covid researchers looked at COVID-19 deaths in late January in mid-April and found a more significant number of Black counties. So how can we decrease the number? They can avoid people working, get better income and jobs, and try to get a good education by listening to school so that later in life, they can get a good job. And some ways we can help underprivileged people is to have more Black and Latino-owned businesses so that they can treat them right and make more organizations that can help others and provide supplies for them, um, nonprofit organizations. And then why? So, there are many deaths because of the injustice from other people in jobs treating them wrongly, racism, and discrimination.

Madison used data to make informed decisions using mathematics in a real-world scenario. Based on her observation about the number of deaths, she inferred that the number of deaths was due to the injustice of low-paid workers having to report to work.

The inquiry into the mathematical experience of the students engaging in culturally relevant cognitive demanding tasks revealed several elements. Students asked and answered questions while completing the tasks. In addition, students shared their thoughts and conclusion, contributing to class discussions. Moreover, the students created visual artifacts to share their mathematical learning and artifacts.

Additionally, the students displayed evidence of the features of the CRCD mathematical tasks. Students related the concepts to their lives. Also, students represented their mathematical ideas in multiple ways by exploring and creating equations. Moreover, students asked questions to understand covid 19 better, which affected their communities.

**Summary**

I used content analysis to code and analyzed the data. The focus was to describe the mathematical experiences of the students engaging in the culturally relevant cognitively demanding mathematical tasks. The examination of the data included describing the mathematical experiences focusing on students asking questions, answering questions, completing the task, and sharing information.

Additionally, examples that supported the key features of culturally relevant cognitively demanding mathematical tasks conceptual frame were outlined and demonstrated. The students connected their lives with school by sharing personal stories about graffiti in their cities and family members' work and health experiences during the pandemic. Additionally, students demonstrated high levels of cognitive demands by exploring equations in a non-algorithmic way. Furthermore, students were able to inquire about the legality of graffiti. Finally, students could make recommendations based on the information they researched about Covid-19 and the pandemic.

Students in this study demonstrated the following NCTM process standards when they engaged in the CRCD mathematical tasks:

- Problem Solving
- Communication
- Representation
- Connections
- Reason and Proof

Evidence of the process standard for problem solving for the mathematics graffiti tasks included students using non-algorithmic strategies to find the equations to their pictures. Students communicated with diagrams when they shared their final products on the last day of class. Furthermore, the representation process standards were evident when the students used multiple representations, such as the equations and the corresponding pictures in the Graffiti tasks. Finally, the connections process standards were evident when the students drew pictures of themselves in the Graffiti tasks. Also, the connections process standards were evident in the Covid-19 tasks when the students spoke about the effects of the disease with their family members.

# 5 DISCUSSION

This study investigated African American students' experiences in mathematics as they engaged in culturally relevant and cognitively demanding tasks. This investigation allowed for students' mathematical experiences to be captured. The African American students' experiences were shared using the lens of the constructivist theory of learning. The constructivist theory of learning focuses on students working through challenging problems while reflecting on the experience prompting questions, and promoting discourse. The following questions framed the research questions in this discussion:

1. In what ways do we describe the mathematical experiences of African American students while engaging in CRCD mathematical tasks?
2. In what ways do the National Council of Teachers of Mathematics process standards become evident in the mathematical experiences of African American students while engaging in culturally relevant cognitively demanding tasks?

I sought to examine the experiences of African American students participating in implementing culturally relevant and cognitively demanding mathematical tasks. This chapter describes the African American students' experiences, the culturally relevant cognitively demanding mathematical task features, and the evidence supporting NCTM process standards. Additionally, a counter-story was developed through the students' engagement with culturally relevant cognitively demanding mathematical tasks. Counter-stories are tools that challenge deficit discourse about a marginalized group (Solórzano & Yosso, 2002). The mathematical experiences of the African American students created a counter-story to the dominant narrative of African

American students regarding academic excellence and African American students' participation in mathematics.

**Mathematical Experiences**

The students' mathematical experiences in the study were captured through the engagement of high cognitive demanding tasks using the constructive theory of learning perspective. The constructivist theory of learning states that students constructing their own knowledge might explore concepts in open investigations, raise questions, participate in discourse, and share their learning through various representations (Fosnot & Perry, 2013).

Students in the study explored the concepts of graphing and researching and interpreting data while using high-level mathematical tasks in a cultural context. Students used problem-solving strategies such as guess and check, reasoning strategies such as providing explanations, and representation during the completion of the culturally relevant mathematical task. Problem solving, reasoning, and using representations are all characteristics of procedures with connection and doing mathematics (Stein et al., 2009).

Additionally, the constructivist theory of learning requires that students participate in discourse (Fosnot & Perry, 2013). Students answering questions and sharing information is a form of discourse (NCTM, 2000 & 2014). Discourse also provides opportunities for students to learn mathematics and promotes understanding of mathematical ideas (NCTM, 2000& 2014). Students in this study shared information by answering questions and discussing their findings and exploration. Additionally, discourse helps to develop a mathematical language that promotes mathematical literacy (Moses & Cobb, 2001). Student discussion and discourse connect to academic success as outlined in implementing culturally relevant pedagogy (Ladson-Billings,1995).

Furthermore, the constructivist theory of learning recommends that students ask questions to construct their own knowledge. Students asking questions indicated engagement with mathematics (Hatfield, 1991). Engagement consists of students actively participating in the learning process (Hatfield, 1991). When students ask questions, the students are seeking to process information that will assist in making mathematics sensible (NCTM, 200 0& 2014). Additionally, questions asked by students create a community of learning (NCTM, 2000 & 2014). When students ask questions, it provides the opportunity for other peers to answer the questions.

Finally, the constructivist theory of learning asks that students share their learning through various representations (Fosnot & Perry, 2013). Representations include "drawings, charts, graphs, and symbols" "to communicate mathematics" (NCTM, 2000, p.280). Students in this study used graphs and organized information to display information about Covid-19—additionally, students manipulated equations and set notation to replicate their chosen graffiti picture.

This study described mathematical experiences focused on the students' asking questions, completing the task, answering questions, and sharing information. Students' mathematical experiences were displayed through students asking, engaging in the culturally relevant cognitively demanding mathematical tasks, using representations to share information, and asking questions to construct knowledge.

**Features of Culturally Relevant Cognitively Demanding Tasks**

Students explored graphing by using problem-solving strategies related to the cognitive demand of doing mathematics. Recall from chapter 1 that doing mathematics involves using non-algorithmic explorations to investigate a mathematical concept (Stein et al. 2009).

The students made connections to their personal lives while engaging in culturally relevant cognitive demanding tasks. A particular student shared that a family member is an artist who makes a living painting graffiti murals. Another student shared examples of a mural that they observed while driving through their neighborhood. The context of the problem had personal connections for the students. The Covid -19 task sparked discussions on how the pandemic affected their families, schools, and day-to-day experiences like grocery shopping. Students spoke of family members being unable to work because of the pandemic. The personal connections made the content more meaningful and displayed a connection between math instruction and their lives.

Furthermore, the Covid-19 task investigated statistical data regarding African Americans and other minority groups. The high percentages of deaths amongst African Americans made the students question why businesses were still open. The students engaged in a discussion about how the pandemic caused them to fear for their family members' safety since some of the family members were deemed essential workers. The data the students researched allowed them to make sense of Covid-19 by exploring the data and personally seeing the effects on them. The students gathered the data and made inferences about the data.

**Connections to the NCTM Process Standards**

The National Council of Teachers of Mathematics assembled standards that guide the teaching and learning of mathematics. The NCTM five process standards are problem solving, reasoning and proof, communication, connections, and representation. The data analysis provided instances where the process standards were evident during the implementation of the culturally relevant cognitively demanding tasks. The research results suggest that students engage in four out of five process standards when engaging in culturally relevant mathematics tasks in a virtual setting. (Discuss reasoning and proof and inductive reasoning)

The findings suggest that when implementing mathematical tasks, the process standards are part of acquiring content knowledge (NCTM, 2000 & 2014). When implementing high cognitively demanding tasks, students may represent math in multiple ways, explore concepts, find multiple pathways to solutions, and access knowledge relevant to their experiences (Stein et al., 2009). Some components of higher-level cognitively demanding tasks share the same key process as NCTM (2000 & 2014) process standards. For example, representing math in multiple ways coincides with the representation process standard. Additionally, solving problems in multiple ways aligns with the problem-solving process standard, which focuses on using different strategies to solve problems.

Furthermore, as stated in the literature in chapter 2, the process standard supports the learning preferences of African American students (Berry, 2003a). Recall that the communication standard supports the relational learning style of African Americans (Berry, 2003a). Finally, the connections process standard focuses on the relationships of concepts with students' interests.

**The Intersection of Constructivist Theory of Learning and Critical Race Methodology**

The constructivist theory of learning asserts that knowledge is created through experiences of cognitive acts (Confrey, 1990). Students learn from a constructive perspective, engage in challenging open-ended questions, formulate and test conjectures, and share their ideas and mathematical knowledge (Fosnot & Perry, 2013). CRCD mathematical tasks are mathematical activities that allow students to use mathematics to focus on issues relevant to their lives (Mathews et al., 2013).

Researchers such as Martin (2009b) and Jett (2012) recommend that any time you examine African American students from a research point of view, race should be part of the investigation. Critical race methodology is the analytical tool that examines the racial underpinnings in mathematics education as it relates to curriculum and the opportunity to learn standards (Davis & Jett, 2019). Critical race methodology interrogates the structures of racism and "intervenes on the various racial taxes and racial shelters" (Anderson, 2019, p.22). In addition to uncovering systemic racism, critical race theory and methodology illuminates the experiences of marginalized groups by giving them a "voice" (Solórzano & Yosso, 2002; Terry, 2011; Davis, 2019).

The culturally relevant cognitively demanding mathematical task allowed the students in this study to engage in high-level tasks. Stein et al. (2009) stated that using higher-level cognitive tasks in mathematics includes students following procedures to explore mathematics connections to communities and concepts and exploring mathematics in a nonalgorithmic approach, which requires students to access relevant information and experiences while working on a task. Similarly, the constructivist theory of learning from Fosnot's and Perry's (2013) perspective requires students to work through challenging problems while reflecting on their experiences through multiple representations. The CRCD tasks were the challenging questions from this study's constructivist theory of learning requirements. The implementation of the CRCD mathematical task provided an opportunity for African American students in this study to engage in challenging mathematics, which is a feature of the constructive theory of learning. It produces a counter-story to the dominant discourse and practices of students of color engaging in non-rigorous mathematical instruction. Critical race theory legitimates student voices and experiences (Berry, 2003a; Ladson-Billings & Tate, 1995). This study provided a narrative that portrays African American students engaging in high-quality mathematics, countering the deficit discourse surrounding African American students.

**A Mathematical Counter-story**

Aydan, Mason, John, Roger, Lennette, Kori, Madison, and Moni logged into the Zoom meeting on the first day of my class, eager to see what the new mathematics elective would bring. The class opened with introductions and discussions about students' likes and dislikes. Aydan, Mason, John, and Roger are shown a video titled “Graffiti: Art or Vandalism?” After a brief discussion, the young men are off on an internet scavenger hunt, searching for information about the origin of graffiti. The young men discovered that the first artist of Graffiti looked like them. Next, Aydan Mason, John, and Roger started entering math terms related to shapes and mathematical concepts such as scaling. They rushed to identify the mathematics in a mural from WebQuest. The lesson for the day closed when students examined a different mural and verbally identified the mathematical terms like polygons, triangles, circles, and trapezoids observed in the graffiti mural.

Day two started with something new. The group of eight was challenged to use a new tool to explore mathematics for the first time. The website was entered into the chat, and the exploration began. Students were asked to modify the equations to recreate the picture of the house plastered on the screen. John asked ‘How do I move the line? What do I have to do with b? The instructor asked, “what number is it pointing at? John shared, “They are pointing at 1.5. At this moment, John was investigating how the y-intercept affects a graph. Kori proclaims, “So if y =10 and the curly brackets, negative 10. How would you do the right brackets? At this moment, Kori was setting boundaries for linear equations. Madison, “how do you get the alligator mouse with the line under it? Madison was also setting boundaries using less than and equal to using inequalities.

Day three brought on even more explorations. The students were given sample equations to create a sample graffiti picture. Aydan shared different numbers to place in the equations to create graphs. Aydan was alluding to changing the intervals on the graph so the lines would display. Mason, “I am trying to do the same thing.” Middle school students have just explored graphing in the cartesian plane, paying attention to the graphing intervals so the graphs are visible.

On days four and five, the great eight brought their pictures to upload in Desmos and began to input equations to fit the image. Kori, “I have an Atom; I will need a lot of circles” Lennette, “I have my drawing that I did to share.” The students worked feverishly and continued to work until presentation day.

Week two was a brand-new start to new, culturally relevant, cognitively demanding mathematical tasks. Aydan, Mason, John, Roger, Lennette, Kori, Madison, and Moni logged in at their normal time. The discussion began with a KWL about the pandemic. The students shared knowledge that they had heard in the news. Next, a video of doctors lecturing about the disparities amongst African American students was viewed. The students immediately started asking “what if” types of questions. Aydan wanted to know why Africa does not have adequate healthcare to fight the pandemic. Lennette shared how the pandemic has disrupted her life. Madison wanted to know why people were not following the rules of the Covid protocol. Even though there were no mathematical calculations, the students were reasoning and concluding the information they received.

The next day the students completed another Desmos activity. The students explore the rate of change in lines. The activity used graphs and different points to conceptualize the rate of change.

The following two days were research days. Not much chatter was happening online. Now and then, you may hear what credible sites are. Mason asserted always to use .gov for facts. Madison found some data and did not know how to convert it to a graphical form. Kori came to the rescue to share her strategy. Students in this activity were collecting and analyzing data from resources they found.

The final day of camp was bitter-sweet. Aydan, Mason, John, Roger, Lennette, Kori, Madison, and Moni were there for the last class. At the beginning of the class, I said my thanks and praised them for all of their hard work. The final day was the opportunity to share their work from either task.

Lennette," This is my infographic, …. So how can we decrease the number? Avoid people, get a better income, and try to get a good job. " Lennette concluded that people with good jobs could stay at home and not be put in harm's way. She drew this conclusion based on the data she found.

Madison" I want to know how just to decrease the numbers."

Lennette" I would say we should go to parties and only go to essential places. Also, to wear a mask." Lennette was eager to share her findings with Madison about decreasing the number of cases for African American students. John presented his conclusions, "And this graph shows how; how much for how many confirmed cases globally have been happened" This statement was made while sharing a graph.

The above counter-story shared instances where middle school students were learning concepts, including graphing, statistical analysis, and interpretations of data. The content presented in the mathematical task was concepts that may be taught in high school. The students persevered and learned new tools to explore mathematical concepts. Implementing the tasks suggests that African American students can engage in content requiring problem-solving strategies.

**Implications**

Moreover, students demonstrated the process standard for problem solving. According to NCTM (2000), problem solving includes the following

> "using diagrams, looking for patterns, listing all possibilities, trying special values of cases, working backward, guessing and checking, creating an equivalent problem, and creating a simpler problem" (p. 54).

Additionally, NCTM (2014) stated that "when students learn to represent, discuss, and make connections among mathematical ideas in multiple forms, they demonstrate deeper mathematical understanding and enhanced problem-solving abilities "(p.24). Students chose a Graffiti picture to import and replicated the picture using equations. This study consistently adjusted their equations and approach to completing the task. Implications

This study intended to describe students' mathematical experiences engaging in culturally relevant mathematical tasks. This study potentially implies classroom practice and research. Regarding classroom practice, students engaging in culturally relevant activities are more likely to experience success in mathematics. It is recommended that teachers utilize students' communities to teach mathematics. This research study captured students in problem solving, communicating mathematics, and representing mathematics in context. I posit that teachers incorporate culturally relevant cognitively demanding tasks to assist with the teaching and learning of mathematics.

I employ district-level curriculum writers to incorporate culturally relevant cognitively demanding tasks into their curriculum. This research study supports the student's opportunity to learn—the mathematics framework. Tate (2005) recommended that the opportunity to learn includes challenging mathematical tasks. Additionally, Stein, Smith, Henningsen, and Silver (2009) have shared the results of implementing high cognitively demanding tasks with the Quasar project.

**Suggestions for Further Research**

Implications for future research entail other researchers employing more research surrounding students' experiences and perceptions of using culturally relevant pedagogy. A limited amount of research currently focuses on African Americans engaging in cognitively demanding tasks and cultural activities. Many of the studies focus on the teachers creating and implementing such tasks. More research is needed that focuses on students.

Another suggestion for future research is to examine the attitudes and behaviors of gender-based classes while engaging in culturally relevant cognitively demanding tasks. The middle school class was divided by gender. It is worth researching variables as it relates to single-gendered classrooms.

Mathews et al. (2013) began with a framework with teachers creating culturally cognitively demanding mathematical tasks. It is recommended that the teachers implement the lesson and link it to student achievement. The likely results will inform practitioners as well as academia.

Stein et al. (2009) suggested that when implementing mathematical tasks, the teacher’s actions be investigated to see if the cognitive demand of the tasks was maintained. Studies that investigate the teachers' actions would benefit practitioners by sharing factors that maintain the cognitive level of the task. Additionally, the factors that support the cognitive decline of a task are important so practitioners can avoid those actions.

Finally, repeating the same research student face-to-face would provide additional implications. Comparison studies could evolve, contrasting the similarities and differences in settings. The change in settings may provide different implications. Furthermore, interview data may add more In-depth descriptions for a counter-story

**Conclusions**

Using a qualitative case study methodology situated in a constructivist theory of learning, this research study investigated the mathematical experiences of African American students engaging in culturally relevant cognitively demanding mathematical tasks. The study addressed the following research questions:

1. In what ways do we describe the mathematical experiences of African American students while engaging in CRCD mathematical tasks?
2. In what ways do the National Council of Teachers of Mathematics process standards become evident in the mathematical experiences of African American students while engaging in culturally relevant cognitively demanding tasks?

Evidence of the NCTM (2000) process standards emerged as the students engaged in the CRCD mathematical tasks. This final chapter connects this study to literature, discusses implications for practice, and offers recommendations for future research.

The literature surrounding classroom instruction for African American students recommends that culture be a part of the instruction (Berry, 2002a; Ladson-Billings, 1997; Malloy, 2009). Culturally relevant teaching entails providing instruction that builds on the students' cultural strength and community (Ladson-Billings, 2004). Additionally, including culturally relevant pedagogy in educational activities has its benefits—chapter 2 highlighted studies incorporating culturally relevant pedagogy in classroom instruction and intervention programs.

Milner (2010) discussed the empowerment of students after engaging in culturally relevant activities. Students in this study felt empowered after engaging in the CRCD mathematical task. For example, a participant affirmed how participating in this activity renewed her love of art and brought awareness to the murals and graffiti in their community.

Furthermore, students that engage in culturally relevant activities tend to develop a social conscience (Ladson-Billings,1995). One of the activities revealed double standards for graffiti in certain neighborhoods. Students questioned whether art should be a punishable offense since it is a form of art expression. It was noted that certain neighborhoods allow graffiti, and other neighbors penalize artists for drawing. Additionally, students that engage in culturally relevant activities may experience success. Academic success is defined as acquiring the necessary tools to apply mathematics throughout their lives (Leonard et al., 2010). This study adds to the examples of implementing culturally relevant activities with students.

Implementing culturally relevant cognitively demanding mathematical tasks in this study allowed African American students' mathematical experiences to be captured and observed. Chapter 1 conceptualized mathematical experience as events that may influence mathematical knowledge and understanding. Additionally, Hatfield (1991) provided characteristics of high-quality mathematical experiences for students. These characteristics were later connected to NCTM's (2014) Process Standards in Chapter 2. Data from this study demonstrated the Process Standards in action. Communication and discourse occur when there is a "purposeful exchange of ideas through classroom discussion and other forms of verbal, visual, and written communication" (NCTM, 2014, p.29). It is noted that "the discourse in the mathematics classroom gives students opportunities to share ideas and clarify understandings, construct convincing arguments regarding why and how things work, develop a language for expressing mathematical ideas, and learn to see things from other perspectives" (NCTM, 2014, p.29). Students demonstrated the communication standards by using appropriate mathematical language to describe concepts. Furthermore, students shared their graffiti task and their Covid-19 findings using mathematics terminology. During the presentations, students agreed with their peers. Students who demonstrate meaningful discourse are "listening carefully to and critiquing the reasoning of peers, using examples to support or counterexamples to refute arguments (NCTM, 2014, p.35). Additionally, students are "seeking to understand the approaches used by peers by asking clarifying questions, trying out others' strategies, and describing the approaches used by others. (NCTM, 2014, p.35)

Moreover, students demonstrated the process standard for problem solving. According to NCTM (2000), problem solving includes "using diagrams, looking for patterns, listing all possibilities, trying special values of cases, working backward, guessing and checking, creating an equivalent problem, and creating a simpler problem" (p. 54). Students employed some of the problem-solving strategies such as guess and check, trying special values, and using diagrams while completing the tasks. Problem solving generates new knowledge from old knowledge (Morton, 2014). Students used their prior knowledge of graphing points, created equations, and interpreted information from a graph. Furthermore, problem solving develops mathematical understanding and assists with developing learners of mathematics (Morton, 2014). Students expressed gratitude for learning new tools and concepts that will be utilized as they matriculate.

Additionally, NCTM (2014) states that "when students learn to represent, discuss, and make connections among mathematical ideas in multiple forms, they demonstrate deeper mathematical understanding and enhanced problem-solving abilities "(p.24). Students selected a Graffiti picture to import and replicated the picture using equations. The students consistently adjusted their equations and approach to completing the task.

Outcomes for implementing CRCD mathematical tasks will vary in relation to the NCTM process standards. Depending on the cognitive demand of the mathematical tasks and the problem being asked to solve, not all NCTM's process standards will connect. For example, a lower-level cognitive demanding task may not promote problem solving and representations. According to Walkowiak, Berry, Pinter, and Jacobson (2018), there is a relationship between mathematical tasks, problem solving, connections, and cognitive depth. Tasks selected with higher cognitive demand tend to facilitate problem solving, connections, and applications (Walkowiak et al., 2018). Furthermore, during the implementation of cognitively demanding tasks, representation, and communication in the form of discourse may be present (Walkowiak et al., 2018). The reasoning and proofs process standard may be present depending on the task that students are required to complete.

Counter-stories provide an avenue for the unheard to have a voice about their experiences (Solórzano & Yosso, 2002). African American students deal with framing the inferiority paradigm regarding mathematics and their performance. It is common to see statements that African American students lag certain groups (Flores, 2008; Darling-Hammonds, 2013). Also, it was noted that African American students are pronged to experiencing low-quality instruction (Flores, 2007; Darling-Hammons, 2013). Furthermore, in Chapter 1, I  revealed startling information from the literature describing the negative effects of standardized testing on African American students. The results often display African American students as inferior to Caucasian students. The paradigm implies that African American students are "predisposed to struggle with mathematics" (Bullock, 2019, p.80). Furthermore, the notion of African American students lagging behind Caucasian students infers that African American students could be fixed "in order for them to engage positively with mathematics" (Bullock, 2019, p.80).

Dominant stories surrounding the instructional experiences of African American students include African American students receiving subpar materials and a lack of quality instruction (Ladson-Billings & Tate, 1995). Additionally, African American students are often subjected to separate instruction focusing on skills (Flores, 2007; Ladson-Billings, 2006; Malloy, 2009). Many of these lacking opportunities are based on race and other biases (Ahorlu, 2012).

African American students in this study had the opportunity to engage in two culturally relevant cognitive demanding mathematical tasks. The counter-story to the deficit discourse is one of the students exploring content not yet learned in school and exemplifying high-order thinking based on the Task Analysis Guide (Stein et al., 2009). The African American students in this study had the opportunity to analyze data from graphs and create recommendations based on the information found. Additionally, students in this study created art by exploring equations using new technology. Students engaged in the concepts of different graphing types of functions and investigated domain and range without formally being introduced to the content. The experience of engaging in higher-level mathematics contradicts the dominant practice of initiation-response-evaluation, where students are shown how to solve problems (Berry & McClain, 2009).

Implementing the CRCD mathematical tasks revealed the connection to the process standards. The process standards describe how students engage in mathematical content (NCTM, 2000, 2014). The process standards support developing students into problem solvers and using mathematics in real-life situations (NCTM, 2014). This study showed that when engaging African American students in CRCD mathematical tasks, the process standards become evident through observations of their mathematical experiences.

This study confirms the domains of culturally relevant pedagogy (Ladson-Billings, 2014). Students in this study exemplified academic success. High-level cognitive demanding tasks presented in the study allowed middle school students to explore content taught in high school. The tasks involved the concepts of graphing functions, transforming functions, evaluating domain restrictions, interpreting data, and conjecting based on the information received. Students in the study illustrated cultural competence, where students learn and celebrate their cultures (Ladson-Billings, 2014). For example, a participant expressed how participating in this activity renewed her love of art and brought awareness to the murals and graffiti in their community. Personal choice represented cultural competence. Student's made personal choices by selecting their graffiti picture to create, customizing the graffiti picture with colors, making decisions on the type of infographic to use, and choosing the infographic format. Culturally relevant instruction coupled with higher cognitive demanding tasks provided opportunities for students to rigorous, relevant curricula that prepare students for the world. Sociopolitical consciousness is the culturally relevant pedagogical domain that prepares students for the real world (Ladson-Billings, 2014). In this study, students evaluated statistical information related to Covid-19 and recommended strategies for decreasing cases and deaths while comparing the transmission rates of non-minority groups with minority groups.

Students in this study had the opportunity to engage in mathematics using rigorous and challenging mathematics tasks in a cultural context. The rigorous tasks promoted problem solving, reasoning, connections, communication, and representation. Students constructed their knowledge by extending mathematical ideas and concepts beyond the middle school curricula, in addition to mathematics content. Participating in the culturally relevant tasks gave students a personal choice. Personal choice allowed students to connect mathematics to their lives and communities. Personal choice supports cultural competence and motivates the students to persevere while gaining knowledge during the immersion of challenging tasks.

The engagement of culturally relevant cognitively demanding mathematical tasks tells a story of African American students immersed in rigorous mathematical content beyond their middle school grade level. The story involves African American students' communicating, problem solving, reasoning, proving, representing, and connecting in mathematics.

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# APPENDICES

## Appendix A

### Graffiti and Mathematics

If you take a look around any major city, you will find street art posted on building, and bridges.

"Graffiti has a rich history in personal expression and designs of mathematics. Graffiti artists find pride in their messages, as they often pertain to social issues or injustices. Graffiti, if defined as writings on the wall, dates to ancient Rome. The urban graffiti that is known today, characterized by spray-paint and vivid colors, appeared first in New York City in the 1960s. Taki 183, who lived in the Washington Heights district, worked as a messenger. As he traveled throughout the city, he would write his name at his various stops, beginning the practice of "tagging. Graffiti is marked by ideas of symmetry, balance, patterns, measurement, and proportion." (Bakewell, 2008, p. 1). Your task is to use mathematical equations to create graffiti art.

Goals: Students will use mathematics to create a mural (street graffiti) using the Cartesian plane

Mathematical Concepts: Graphing functions (quadratic, linear, and exponential).

## Appendix B

### Covid-19 Disparities with African Americans

- Black Americans continue to make up a disproportionate share of Covid-19 fatalities as the number of deaths from the coronavirus pandemic exceeds 100,000 in the U.S., according to an analysis of CDC data.
- Nearly 23% of reported Covid-19 deaths in the U.S. are African American as of May 20, even though black people make up roughly 13% of the U.S. population, according to the data.
- Conditions such as diabetes, hypertension, and asthma that tend to plague African Americans more than other groups could contribute to more Covid-19 deaths. Income inequalities and disparities in access to health care tend to hurt minority and lower-income populations more than others.
- Dr. Anthony Fauci, the nation's leading infectious disease expert and member of President Donald Trump's coronavirus task force, said in April that the coronavirus outbreak is "shining a bright light" on how "unacceptable" the health disparities between blacks and whites are.

(Lovelace, 2020)

**(a) Using reputable resources such as WHO, the CDC or John Hopkins, collect data points pertaining to the infection rate of African Africans and other minorities as compared to the Caucasian population.**

**Compute the rate of the data points you found. Does the data correctly reflect the percentages presented above? Are African American and other minorities currently contracting the covid-19 at a higher rate?**

**(b) Research factors that slow the spread of Covid -19 for African Americans and other minorities. What are some things that can be done to slow the spread?**

**(c) Create an infographic using the information you found to share the information you research with family and friends.**

**Appendix C**

Culturally Relevant Cognitively Demanding (CRCD) Task Description

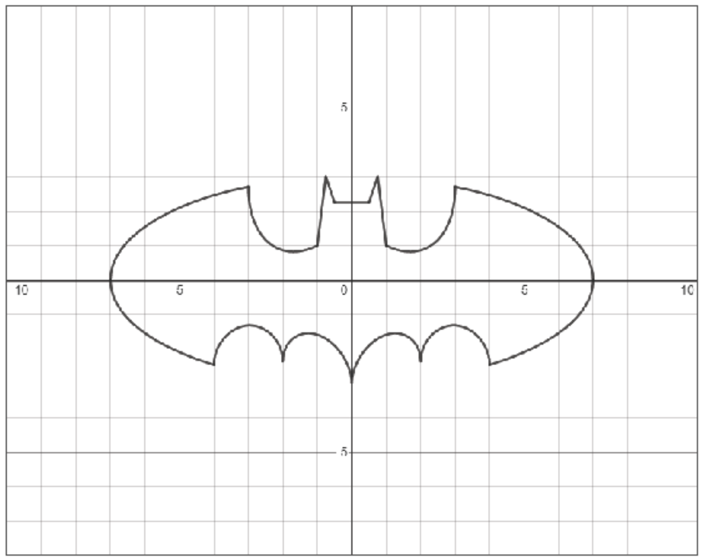
| Description |
|---|
| Mathematics task explicitly requires students to inquire (at time problematically) about themselves, their communities, and the world about them. |
| Mathematics task draws from students' community and cultural knowledge. |
| Task may explicitly seek to add to this knowledge through mathematical activity |
| Task is mathematically rich and cognitively demanding, embedded in cultural activity. |
| Task 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 the world. |
| May draw from connections to other subjects and issues. |
| Task asks students to engage the discontinuity and divide between school and their own lives – home and school. |

Matthews, L. E., Jones, S. M., & Parker, Y. A. (2013). Advancing a framework for culturally relevant, cognitively demanding mathematics tasks. *The brilliance of Black children in mathematics: Beyond the numbers and toward new discourse*, 123-150.

**Appendix D**

Sample Desmos Activity

7/13/2020 Batman




https://www.desmos.com/calculator/dnzfajfpym 1/2

## Appendix E

### WebQuest

# Mathematics in Graffiti Web Quest

Let's learn more about Graffiti?

When did Graffiti become popular? https://www.sprayplanet.com/blogs/news/a-history-of-graffiti-the-60s-and-70s *

Long answer text

Who was the first Graffiti artist? https://www.sprayplanet.com/blogs/news/a-history-of-graffiti-the-60s-and-70s

Long answer text

What type of math content can be found in graffiti? https://sites.google.com/site/culturemathematics/mathematics-content

Long answer text

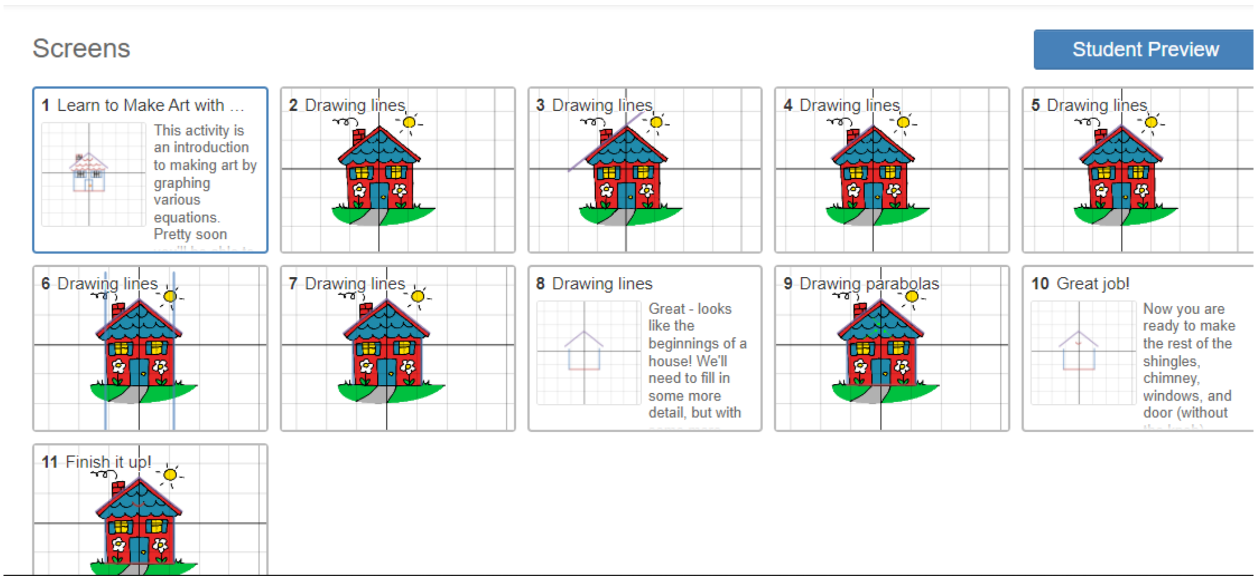
What type of math content do graffiti artists utilize? https://caamedia.org/blog/2015/01/14/learnmathwithgraffiti/

Long answer text

https://docs.google.com/forms/d/1f4Syph5pcBdhEQKNg9KqyhXkAuuGlujfdKGnSxkf9Qo/edit 1

## Appendix F

### Desmos Art Activity



**Appendix G**

Types of Equations

Types of
Equations

Equation Type of Equation Boundary $x = 4$ $\{0 \le y \le 4\}$ Vertical line Starts at 0 and stop at positive 4

$y = 2x + 2$ $\{1 \le x \le 3.5\}$ Increasing line Starts at 1 and stop at positive 3.5

$y = -2x + 2$ $\{1 \le x \le 3.5\}$ decreasing line Starts at 1 and stop at positive 3.5

$y = 4$ $\{0 \le x \le 4\}$ horizontal line Starts at 0 and stop at positive 4

$y = x^2 + 3$ $\{1 \le x \le 5\}$ Parabola (u-shape) Starts at 1 and stop at positive 5

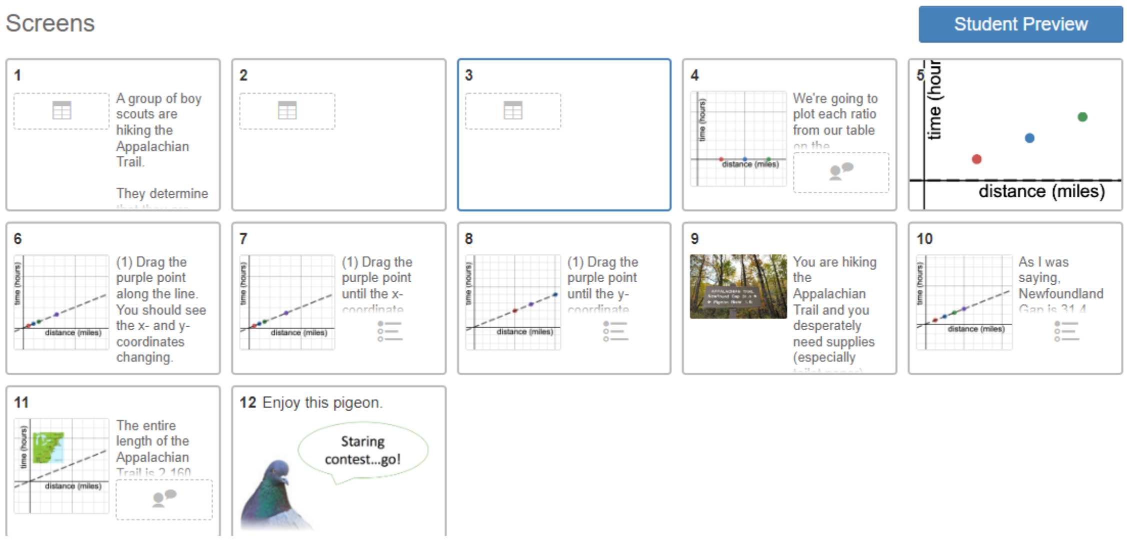
$y = -2x^2 + 5$ $\{1 \le x \le 5\}$ Parabola (n-shape) Starts at 1 and stop at positive 5

$(x - 2)^2 + (y + 2)^2 = 16$ Circle Center is at (2,-2) with a radius of 4 (3,6) point A dot

Desmos.com/activitybuilder/custom/57459e16b2e739f205183314

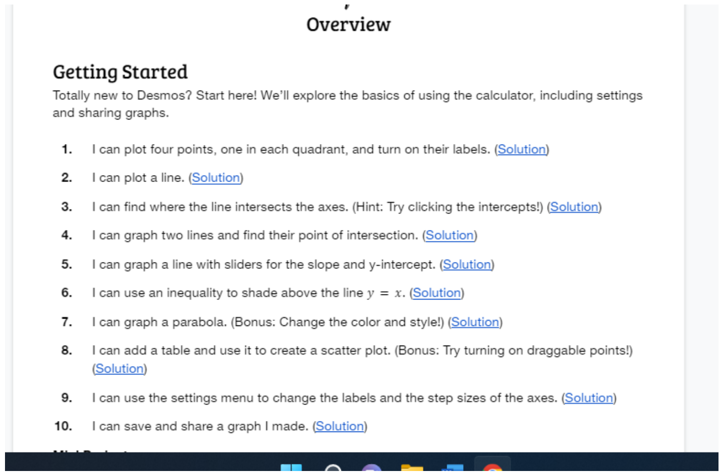
Appendix H

Desmos Rate of Change Exploration



## Appendix I

Desmos Scavenger Hunt



### Overview

#### Getting Started

Totally new to Desmos? Start here! We'll explore the basics of using the calculator, including settings and sharing graphs.

1. I can plot four points, one in each quadrant, and turn on their labels. (Solution)
2. I can plot a line. (Solution)
3. I can find where the line intersects the axes. (Hint: Try clicking the intercepts!) (Solution)
4. I can graph two lines and find their point of intersection. (Solution)
5. I can graph a line with sliders for the slope and y-intercept. (Solution)
6. I can use an inequality to shade above the line $y = x$. (Solution)
7. I can graph a parabola. (Bonus: Change the color and style!) (Solution)
8. I can add a table and use it to create a scatter plot. (Bonus: Try turning on draggable points!) (Solution)
9. I can use the settings menu to change the labels and the step sizes of the axes. (Solution)
10. I can save and share a graph I made. (Solution)

**Appendix J**

**Graffiti Mural**

Art of the S.W.A.T.S House retrieved from https://www.atlantamagazine.com/news-culture-articles/elevate-s-w-a-t-s-celebrates-southwest-atlanta-and-a-new-mural-at-westgate-shows-of