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How to Do QuantCrit: A Reflexive Account of Applying Critical Quantitative Methods to a Study of Black Women in STEM

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HOW TO DO QUANTCRIT: A REFLEXIVE ACCOUNT OF APPLYING CRITICAL QUANTITATIVE METHODS TO A STUDY OF BLACK WOMEN IN STEM

by

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HOW TO DO QUANTCRIT: A REFLEXIVE ACCOUNT OF APPLYING CRITICAL QUANTITATIVE METHODS TO A STUDY OF BLACK WOMEN IN STEM

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There has been extensive research into the underrepresentation of minoritized students in STEM disciplines since the 1990s with limited success in improving the representation of Black women in math-intensive STEM fields. This dissertation aims to address how the guiding tenets of critical quantitative (QuantCrit) methods work when used with publicly available datasets and commonly used statistical approaches. Additionally, this dissertation provides a framework for how to apply reflexivity as a method while utilizing a QuantCrit approach. The publicly available HSLS:09 dataset is used as part of a reflexive study to demonstrate how the tenets of Critical Race Theory (CRT) map onto a QuantCrit study utilizing structural equation modeling. Through personal, methodological, and conceptual reflexivity, disconnects between the tenets and the QuantCrit study are highlighted and discussed. These findings indicate a need for more robust guidelines surrounding QuantCrit research. Furthermore, publication access must be expanded to encourage movement beyond traditional White ways of knowing.

Dedication

This dissertation is dedicated to my mother, Dr. Sarah Parsonson, and my stepfather, Dr. Peter Parsonson, who continue to model the values of a strong work ethic and service to others.

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Table of Contents

List of Tables

List of Figures

List of Appendices

Chapter 1

Introduction

This dissertation is my reflexive account of attempting to conduct a critical quantitative research study of Black women pursuing STEM degrees at two or four-year colleges and universities. I examined how tenets of critical quantitative (QuantCrit) methods in higher education could be applied to traditional quantitative approaches for studying Black women in STEM. As a White woman and developing researcher, I am both receptive to my quantitative training in conducting higher education research as well as the critical perspective that traditional quantitative approaches are problematic for a variety of reasons, a main reason being that quantitative approaches reduce race to a background variable and cannot account for the complexity of racialized experiences among People of Color (Zuberi & Bonilla-Silva, 2008). On the one hand, higher education researchers have conducted countless studies using Black and other Students of Color as a sample. On the other hand, a large body of qualitative studies document the complex, nuanced, and complicated experiences of racially minoritized populations. How can these approaches be reconciled? Should they be reconciled? As a student learning about critical race theory (CRT) as well as quantitative research approaches, I decided to focus on questions around how to bring both approaches together. While proponents of quantitative critical research (QuantCrit) posit that quantitative research techniques and statistics are viable methodologies to study underrepresented groups in STEM (Garcia, López, et al., 2018; Garcia, Vélez, et al., 2022; Gillborn et al., 2018; Suzuki et al., 2021), there are limited exemplars that lay out a path for performing QuantCrit research

(Castillo & Gillborn, 2022). To fill this research gap, I will draw on reflexivity as a method to explore how quantitative critical (QuantCrit) analysis and scholarship can be specifically applied to a quantitative study of the experiences of Black women in STEM. At its heart, this study is a methodological study designed to advance the utilization of reflexivity and tenets of CRT in advancing social justice for minoritized students in STEM higher education.

There is an abundance of research literature on Black and other marginalized groups within science, technology, engineering, and math (STEM) disciplines, yet there remain significant barriers to access, persistence, and retention for undergraduate students in these fields. This has significantly negative consequences for the nation in terms of talent and economic loss, but is devastating, primarily, in terms of social injustice for the individual students who intend and want to pursue these fields. Diversity in STEM within the context of the United States has been explored extensively since the early 1990s with an overwhelming discourse surrounding historically underrepresented (HU) students - racial and ethnic minorities, women, and first-generation college students (Bettencourt et al., 2020; Estrada et al., 2016; Sax et al., 2017). Despite almost 30 years of research and attempts to improve representation in STEM disciplines through changes in policies and practices, persistent racial/ethnicity and gender gaps remain in some STEM subdisciplines. Improvements in representation of HU students have occurred in the specific STEM subdisciplines of psychology, biosciences, and social sciences (Hale & Burke, 2017). The subdisciplines that continue to maintain the most notable gaps in achievement for underrepresented students are math-intensive fields – physical science,

math and statistics, engineering, and computing science (Lehman et al., 2017; Su & Rounds, 2015). The limited progress regarding racial equity within STEM despite countless studies with an empirical emphasis on Students of Color is troubling. A central problem with STEM higher education literature is that it centralizes racial minority status without engaging explicitly in issues of race and racism (Abrica, 2022; Abrica et al., 2021). Specifically, researchers often treat race in reductionist ways methodologically and conceptually (Abrica et al., 2021). Quantitative studies of racially minoritized students in STEM inherently group individuals into racial categories for the purposes of understanding intra- and intergroup differences. The consequence of this, as critical methodologists and critical race scholars have pointed out, is the obfuscation of intersectional and complex social experiences of students (Abrica et al., 2021).

Within the STEM equity cannon of literature, scholars have focused on gender inequity, racial inequity, and sometimes the intersection of the two (Van Dusen et al., 2022). While acknowledging that multiple intersecting minority identities exist and that there is hierarchy within social categories (Cole, 2009), Crenshaw (1991) critically observed that membership within two social groups brings with it a unique experience of oppression that is informed by interrelated structures. She argued, using Critical Race Theory, that Black women, for example, experience intersecting forms of oppression based on both race and gender. The complexity of intersectionality is not always captured in the literature specific to STEM equity in higher education. The reason is because, as Abrica et al. (2021) point out, higher education tends to rely on rigid quantitative approaches that do not "fundamentally, invest in the knowledges and nuanced identities

of Students of Color, nor do they center theories of race and power in their operationalization" (p. 4). STEM equity research in higher education, by relying on quantitative analyses that treat students' racial identities as background variables, diminishes racial identities and experiences in linear, predictable, and reductionist ways (Abrica et al., 2021). On the one hand, there is a vast body of largely quantitative research examining experiences of Black women and other students who may hold multiple, and intersecting identities. On the other hand, there is a critical body of scholarship that advances the idea that experiences and outcomes of racial minority students cannot and should not be reduced to background variables to be plugged into a reductionist model. In this dissertation, I explored how to potentially reconcile two divergent approaches to the study of Black women in STEM: one approach is a traditional area of STEM scholarship that largely uses nationally available data and statistics to examine established constructs like self-efficacy, belonging, and identity. The second approach is critical and qualitative in nature, focusing on intersecting forms of oppression as they shape experiences and outcomes for Black women in STEM. By juxtaposing these two frames and relying on reflexivity as a method, I explored how Women of Color, as a demographic group, can and should be studied in STEM higher education, with an emphasis on the smaller subset of Black women.

As a point of clarification, this study was methodological in nature rather than empirical. What this means is that I was not relying on a traditional qualitative or quantitative study to answer an empirical question of student experiences and outcomes in STEM fields. Rather, this dissertation research centered the study of a method or

approach by which we, as higher education scholars and practitioners invested in promoting more meaningful equity in STEM fields, should study Black women in STEM. Thus, the questions explored in this study are focused on the research tools we use and their consequences and implications. Drawing on a qualitative, reflexive approach for studying educational research methods, I sought to understand how one might use a structural equation model within the quantitative tradition to execute a study of Black women that *does not* perpetuate reductionist views of race or racially minoritized groups. In other words, situated between traditional quantitative STEM scholarship and more critical race scholarship, I examined how one might go about using critical quantitative (QuantCrit) methods in higher education. To this end, I focused on examining the tenets of critical quantitative methods and understanding how QuantCrit methods can be used specifically with publicly available datasets and commonly used statistical approaches in STEM higher education. Additionally, I focused on identifying, using a reflexive approach, the utility and feasibility of applying critical race theory tenets to a quantitative study of Black women in STEM. Ultimately, although the quantitative approach of structural equation modeling was used in this dissertation, the dissertation itself was a reflexive, methodological study. I utilized a large dataset and a quantitative research approach as a vehicle for exploring how, as a White woman and beginning researcher, to study Black women pursuing STEM fields.

Background and Impetus for the Study

Prior research on Black women in STEM education has pointed to factors that threaten enrollment, persistence, and degree completion but typically overlooks the

overarching issue of a racialized and gendered environment (McGee & Bentley, 2017). A few of the factors linked to disparities in STEM outcomes for racial/ethnic minorities and women include systemic racism, a "chilly" climate at the level of campuses and STEM classrooms, a lack of a science identity, and STEM pedagogy that is not culturally relevant (Carlone & Johnson, 2007; McGee, 2020; Solorzano et al., 2000; Walton et al., 2015; White et al., 2019). While self-efficacy is a factor in all students, there is some research indicating that self-efficacy and its importance in acting as a motivating factor in education may vary across racial/ethnic groups (Usher & Pajares, 2008) and gender. Despite the variation in self-efficacy seen across racial/ethnic groups, some researchers argue against race-comparative studies because this type of analysis positions race/ethnicity as a problem and continues to support negative stereotypes of Black culture as deviant and dysfunctional (Gibbs, 1988; Majors & Billson, 1992; Parham & McDavis, 1987; as cited by Jackson & Moore, 2006). My study focused on utilizing a critical lens and reflexivity to examine how we, as researchers, can move forward and expand our understanding of underrepresented students in STEM through quantitative studies. As a White woman, I used personal reflexivity to consider my role in engaging with scholarship surrounding racially minoritized students.

As a larger group, racial/ethnic minorities and women comprise 70% of college students but earn less than 45% of the degrees in STEM disciplines (Office of Science and Technology Policy, 2016) and represent a large pool of individuals who are experiencing social injustice due to their race and/or gender. The race-based experience of Black students is relevant because, as a group, the percentage of math-intensive

engineering and computer science bachelor's degrees awarded to Black students has not only failed to increase from 2008 to 2018 but has declined. Over the ten-year period from 2008 to 2018, bachelor's degrees awarded to Black students in engineering, as a share of all engineering degrees, decreased from approximately 5% to 4% and computer science degrees decreased from approximately 11% to 9% (Hamrick, 2021). During this same period, Latino/a/x students, another sizable minoritized group, saw an increase in their share of bachelor's degrees in engineering and computer science from approximately 8% to 12% and from 8% to 11%, respectively (Hamrick, 2021). Like Black men, Black women experienced a decline in the percentage of degrees in computer science, math and statistics, and engineering between 2008 and 2018 although for Black women in STEM, the number of degrees from associates to doctorate degrees in science and technology was higher than the number of those degrees in the same fields for Black men with the exception for engineering at all levels (NCES, 2021).

Black women in STEM fields have unique lived experiences that separate them from Black men and women of other races/ethnicities. While Black women share racial discrimination with Black men and gender discrimination with White women, their experiences are distinct because their experiences are significantly shaped by both racism and sexism. Black women experience racism in the forms of racial microaggressions and negative college campus climates (Estrada et al., 2016; Lee et al., 2020; McGee & Bentley, 2017; Smith et al., 2016) in addition to sexism, specifically within STEM disciplines (Nissen et al., 2021; Van Dusen et al., 2022). It is these multiplicative experiences that make Black women a distinctive group. These experiences also lead to

Black women being a “hidden” group when issues are explored by examining Black students or women more broadly without addressing the intersectionality of the racialized and gendered experience of Black women (Crenshaw, 1991; Ireland et al., 2018).

Although Women of Color comprise 20% of the U.S. population, they earn only 14% of bachelor’s degrees in STEM fields (National Center for Science and Engineering Statistics, 2021). Intertwined with the race-based gap is the gender gap experienced by women in traditionally male-dominated STEM fields. I explored the intersecting gender-based experience of Women of Color, with a primary focus on Black women, in STEM disciplines because women face gender stereotypes in STEM (Beasley & Fischer, 2012; Walton et al., 2015). The lack of progress in improving success rates for Black women students in the STEM subdisciplines of engineering and computer science indicates a need for continued research into the underlying explanatory factors driving this disparity as evidence-based interventions rely on this critical information.

Much of the literature surrounding the impacts of racism and sexism on Black women in STEM has utilized qualitative approaches or focused on theory. A major area of focus in STEM literature is on racially minoritized groups and, to a lesser extent, literature specific to racially minoritized women is on self-efficacy, identity, and sense of belonging. Collectively, self-efficacy, identity, and sense of belonging are identified as major individual-level factors in the recruitment and persistence in STEM subfields. These are individual attributes that need to be contextualized in terms of how they are shaped by race and racism experienced by Black women. This study focuses on how we can contextualize individual-level experiences and outcomes in the context of

understanding how race and racism are experienced by Black women in STEM subfields. Additionally, this study focused on the HSLS:09 data set because large national datasets play an outsized role in providing "evidence" to support policy changes with policymakers emphasizing reliance on quantitative data over qualitative data despite issues inherent in quantitative approaches (Gillborn et al., 2018; Lingard et al., 2012). Considering the amount of money invested in creating large, publicly available datasets, they should be expected to produce valuable data for less represented groups, such as Black women in STEM. Unfortunately though, race has not been easily studied in federal datasets other than as a background variable (Abrica et al., 2021). Rather than arguing against the use of quantitative data in studies of minoritized populations, I argue that effort should be expended by scholars to find the best ways to utilize large datasets in the role of advancing racial justice in higher education. Within the publicly available HSLS:09 dataset, there is consideration for how students perceive the way in which instructors view them along racial and gender lines. These survey items, along with others from the HSLS:09 dataset, were used as part of a reflexive exploration into the value and feasibility of using structural equation modeling in a QuantCrit study of a minoritized population in STEM higher education.

Research Problem

This dissertation reflexively explored a conceptual and methodological problem: the separation or divergence of critical research on the experiences of Black women and traditional, quantitative approaches to studying Black women and other historically underrepresented groups in STEM. While there are strong conceptual and qualitative

approaches in the literature on Black women in STEM, this information is not integrated or incorporated into large-scale quantitative data analysis and reporting that most often is used to guide national policy and discourse. Arguably, this is because of small sample sizes or the inclinations of researchers to compare groups to one another. The problem with having divergent approaches to the study of Black women in STEM — one approach representing a traditional area of STEM scholarship that largely uses nationally available data to examine established constructs like self-efficacy, belonging, and identity, and secondly, an approach that is critical and qualitative in nature, focusing on intersecting forms of oppression as they shape experiences and outcomes for Black women in STEM—is that racial equity in STEM is never realized. There is a gap in understanding how Black women as a demographic group can and should be studied in STEM higher education. Proponents of quantitative critical research (QuantCrit) posit that quantitative research techniques and statistics are viable methodologies to study underrepresented groups in STEM (Garcia, López, et al., 2018; Garcia, Vélez, et al., 2022; Gillborn et al., 2018; Suzuki et al., 2021) but there are limited exemplars that lay out a path for performing QuantCrit research (Castillo & Gillborn, 2022). To fill the gap, I drew on methodological reflexivity to explore how quantitative critical (QuantCrit) analysis and scholarship can be specifically applied to a quantitative study of the experiences of Black women. By doing so, I advanced our understanding in the field of higher education of the challenges and limitations of maintaining a limited perspective on race in the study of Black women in STEM, but also, the challenges and limitations of

trying out critical, quantitative approaches that aim to centralize race while working with traditional quantitative paradigms and tools.

Purpose Statement

The purpose of this dissertation was to explore and understand how to apply critical quantitative approaches in studies of Black women students in STEM higher education research. While many authors cite increasing racial diversity in STEM fields as an economic issue or in terms of building a more globally competitive STEM workforce, both goals centered on interest convergence (Bell, 1980), the goal of improving racial/ethnic and gender diversity within math-intensive STEM subdisciplines of physical science, engineering, mathematics and statistics, and computer science is most significant in terms of achieving social justice. By applying the tenets of QuantCrit, I am centering social justice as the goal in studying Black women in STEM higher education. Other scholars have relied heavily on qualitative approaches and have used individual decision-making frameworks to study Black women in STEM higher education. My study leveraged a federal, publicly available dataset, HSLS:09 data, which tracks students from their entry into high school in 2009 through their college tenure as an example dataset to explore STEM self-efficacy, STEM identity, and sense of belonging in Black women following STEM tracks in college. This dataset allowed me to explore and examine what variables and approaches are possible for studying the racialized experiences of Black women, in STEM, using quantitative methods, while maintaining a critical lens. I used reflexivity as a methodology while conducting a quantitative study of Black women using the HSLS:09 dataset, a nationally available dataset commonly used to study the

constructs of self-efficacy, identity, and belonging. In performing both tasks, I fulfilled the purpose of this study which was to explore and understand how to apply critical quantitative approaches to the study of Black women and, more broadly, minoritized students in STEM higher education.

Significance of the Study

To date, there are still only a few exemplars that indicate how to carry out a QuantCrit study. We lack examples of what QuantCrit looks like in practice in empirical studies and, as a doctoral student, I identified gaps in my own educational background surrounding quantitative research techniques. There is a need to reflexively explore what it looks like to apply the tenets of a QuantCrit framework and how QuantCrit research is experienced by researchers. A central contribution of my scholarship is that it explores boundaries and relationships in real world data between traditional and critical quantitative approaches. It is both critical of structures of oppression (i.e., relying on critical quantitative approaches rooted in critical race theory) (Gillborn et al., 2018; López et al., 2018) while also reinforcing of structures of oppression (i.e., utilizing quantitative methods that reinforce White ways of thinking and epistemological oppression) (Bonilla-Silva & Zuberi, 2008).

From their inception, statistics have been used to reinforce racist hierarchies (Bonilla-Silva & Zuberi, 2008), from the questions asked to the answers presented as "facts" waiting to be uncovered. In societies structured by racialized and gendered domination, such as the U.S., majoritarian assumptions of White, heterosexual men have continued to imbue racist and sexist biases within the statistical methods of traditional or

uncritical quantitative research. Rather than shun certain methods, I argue that we should recognize that biases are embedded in all forms of research and strive to incorporate a critical perspective even in quantitative methods that are ofttimes at odds with the values inherent in critical scholarship. To understand the push to utilize statistics in critical scholarship, rather than restrict critical research to qualitative research, it is imperative to recognize the power of statistical tools within the public arena. Gillborn (2010) explains that quantitative research and numbers are powerful because "numbers carry a special kind of influence in contemporary policy debates, where statistics are generally equated with scientific rigour and objectivity" (p. 272). Borrowing from the Black lesbian feminist Audre Lorde (1984, 2003), "the master's tool will never dismantle the master's house," but if the master's tools hold power and the power cannot be taken from the tool, the tool itself must be reimagined.

Research Question

We know that Black women entering college express an interest in STEM fields at levels higher than White women (O'Brien et al., 2015) yet Black women continue to be underrepresented in the STEM workforce in part because they do not complete a degree in a STEM field at the same rate as White women. We also know that examining the identity, sense of belonging, and self-efficacy of minoritized individuals in STEM disciplines is important. However, there is limited focus on incorporating the roles of structural racism and sexism into quantitative models in educational studies. This study sought to explore how we can move critical quantitative intersectionality research (CRQI) on Students of Color in STEM higher education, especially Black women,

beyond simple descriptive statistics and complement the extensive qualitative counter story studies available by exploring how confirmatory factor analysis and structural equation modeling can be used to test theories from a critical race perspective. The central research question driving this study is: How do the guiding tenets of critical quantitative methods work when used with publicly available datasets and commonly used statistical approaches?

By answering this question, I offer an example of what QuantCrit research looks like in practice in empirical studies, I provide a reflexive, methodological roadmap that others can follow to explore how the tenets of CRT are addressed or not addressed in their own work and the work of others. I also ascertained the utility and feasibility of applying critical race theory and method to a quantitative study of Black women in STEM.

Definitions of Terms

In this study, STEM disposition was operationalized as a student's *interest*, their perception of the *utility* of a given career, their academic *self-efficacy*, and their STEM *identity*. In simplistic terms, one's disposition, in terms of their career, influences whether they enter and remain in a field of study. *Utility* was defined as the relevancy or usefulness of a STEM career at both an individual level of goal achievement and a more collective or societal level from a student's perspective. STEM *self-efficacy* refers to how capable a student views themself in math and science as well as the student's perception of how others view their competency in those disciplines. STEM or science *identity* is closely tied to their self-efficacy but is distinct in that identity is how students view

themselves – as a scientist or an engineer, for example – and believe they are viewed by others, whereas self-efficacy includes the component of perceived capability.

References to "math-intensive STEM subdisciplines" included those subdisciplines in which women and racial/ethnic minorities are currently underrepresented – mathematics and statistics, engineering, and computing science. The acronym MECS was used to refer to these specific subdisciplines within the larger classification of STEM disciplines.

Within STEM higher education literature, "Students of Color" and "Women of Color" conventionally include individuals who identify as American Indian or Alaska Native, Hawaiian Native or Pacific Islander, Asian, Black or African American, or Latina/o/x. Asian Americans are not typically included with other racially and ethnically minoritized students as "underrepresented" in STEM education and, therefore, were not included in my study which centralizes the impact of race and racism on racially minoritized individuals in STEM higher education. In this study, "Students of Color" followed the convention of STEM higher education literature while "Women of Color" was used to refer to racially and ethnically minoritized women who identify as Black or Latina. Black was used as a racial identifier throughout this study although some literature referenced is specific to individuals who identify as African Americans. Studies in which individuals identified as Americans with origins in Africa retain the identifier "African American" rather than generalizing more broadly to Black. In keeping with American Psychological Association standards, racial and ethnic terms are considered proper nouns and are therefore capitalized (American Psychological Association, 2020).

Overview of Methodology

Prior research on Black women in STEM has frequently used aggregated data that groups Black women with other underrepresented students (Estrada et al., 2016) or focuses on institutional barriers (Pierszalowski et al., 2018) and characteristics of Black women that shape their science identity and their persistence in STEM. Within the past ten years, this research has frequently used qualitative methods (McGee & Bentley, 2017) and a social cognitive career theory (SCCT) framework (Byars-Winston & Rogers, 2019; Kurban & Cabrera, 2020a; Sax et al., 2017). While there are some examples of studies utilizing a CRT framework or QuantCrit methods (López et al., 2018), many studies have highlighted the impact of racism and sexism on individuals or within STEM programs and colleges (Priddie, 2020) while largely ignoring the historical context of race and racism in the United States, social injustice, and the ensuing effects on Black women in STEM. Furthermore, while reflexivity is put forth as a viable methodology for exploring our perspectives and assumptions throughout the research process (Lazard & McAvoy, 2020; Nadin & Cassell, 2006), reflexivity remains ambiguous in terms of the process and there are limited examples of reflexivity within QuantCrit studies (Castillo & Gillborn, 2022). To provide an alternative perspective that bridged the gap between divergent bodies of literature, I reflexively explored how the guiding tenets of critical quantitative methods work when used with a large, public dataset and the commonly used statistical approach of structural equation modeling. Reflexivity was used to elucidate the limitations and possibilities for quantitatively studying Black college women in STEM fields from a critical vantage point.

Delimitations

Throughout this study, there was intentionality behind my decisions of what to include, what to exclude, and how to approach my research questions. The delimitations outlined in this section were further explored through reflexivity. I chose to utilize the HSLS:09 dataset for several reasons. Firstly, this dataset is a large, publicly available dataset that includes specific survey responses that allowed individuals to indicate how they felt their instructors in certain STEM courses – engineering, computer science, mathematics, and natural science – treated students of different races and genders. Secondly, this dataset allowed inclusion of self-identified racially and ethnically minoritized women working towards a broad range of STEM degrees at either a two-year or four-year college in the United States. Overall, this government-funded federal dataset is representative of large, longitudinal datasets that policymakers typically rely on as a source of evidence to support national policy changes (Gillborn et al., 2018).

A second delimitation was the choice of aggregating STEM fields rather than disaggregating and only including MECS. This decision was made because of the small sample size of Black women when only considering those in mathematics, engineering, and computer science fields. Inclusion of STEM fields beyond MECS, such as natural science, greatly increases the sample size of Black women in STEM, but also opens the possibility of including individuals who differ from those following math-intensive pathways. I believe the value in including a larger sample size while exploring the limitations and possibilities in a large dataset outweighed the risk of aggregating dissimilar STEM fields in this study.

A third delimitation involved further aggregation to include Latina women in addition to Black women. As reflected in the title of this dissertation, the initial focus of this study was intended to be Black women. Unfortunately, a preliminary examination of the HSLS:09 dataset revealed a small sample size – 218 individuals – who were Black women working towards STEM higher education degrees. Like many statistical tools, a large sample size is required so to allow the use of structural equation modeling, the decision was made to include Latinas with Black women. While this homogenizes and reduces the nuances for subsets of racially minoritized students, this aggregation was required for statistical purposes. This decision highlights one of the reasons why qualitative methods have been preferred - for their ability to capture the nuance of the experiences of minoritized people. My decision to retain a dissertation title indicating a focus on Black women after I felt forced to aggregate Black and Latina women into the unnatural, homogenized category of Women of Color was intentional.

Lastly, a difficult choice was whether to include a third stage of multigroup analysis to compare differences in structural equation models for Black women and White men. White men have traditionally been the most well-represented group in STEM fields and a comparison could potentially highlight differences in STEM disposition in Black women compared to White men. This third stage, multigroup analysis (Keith, 2019), could potentially be used to examine any differences between the models for Black women and White men and the analysis of any differences between the models could be grounded within a CR framework to avoid situating Black women as deficit in any way. However, caution was used throughout this study to avoid any deficit framing

found in earlier scholarship (Gibbs, 1988; Majors & Billson, 1992; Parham & McDavis, 1987; as cited by Jackson & Moore, 2006) and ultimately, I determined that not including a comparison of Black women to any other group of students was central to my conceptual framework.

Limitations

Limitations exist in all research, and I will briefly explore some limitations that existed in this study. One limitation was linked to the use of a dataset that was not designed specifically for this study. Extensive documentation describing the survey questions and data collection methods for the HSLS:09 dataset is available and was used to determine the most applicable survey items, but this dataset was not specifically designed for this study. The discrete options available for survey question answers introduced limitations during data collection that most likely erased gender nonconforming and multiracial individuals. A second limitation was the limited number of Black women in STEM programs captured in the HSLS:09 dataset. The low number of Black women in engineering and computing science programs is frequently cited as a reason for aggregating data or utilizing qualitative methods. As a result, datasets, including the HSLS:09 dataset, typically rely on weighting factors to make extrapolations to larger populations a possibility. Collecting survey data from more Black women in math-intensive STEM fields would be beneficial, but this is currently not feasible because the numbers are quite low, and this was beyond the scope of this study. Additionally, my own limitations existed as a White woman conducting critical quantitative research. A more in-depth analysis of the limitations in this study, including

my personal limitations and limitations of critical quantitative studies in general, are explored through reflexivity and presented in my findings and discussion.

Organization of the Study

Chapter 1 provides an introduction and general overview of the study at hand. Although extensive research on underrepresented students in STEM fields exists, there has been limited study of Black college women, specifically, in STEM and even more limited studies using a critical quantitative methodology. This introductory chapter explains the purpose of this study: to gain insight into how a critical quantitative methodological approach can be applied to research with underrepresented students in STEM fields utilizing a large federal dataset. In addition to exploring the utility of the HSLS:09 dataset in a critical quantitative study, this study investigates extant literature to determine the explication of reflexivity in QuantCrit methodologies and how to perform QuantCrit research.

Chapter 2 provides a review of literature related to race and gender in STEM education as relevant to Black women. Included in Chapter 2 is information about the four constructs that create STEM disposition. Chapter 2 also explains the conceptual framework I used as a lens for this study and the tenets of QuantCrit. Chapter 3 provides a detailed explanation of the methodological approaches I used with an emphasis on reflexivity. My findings are included in Chapter 4, including my reflexive responses exploring the tenets of QuantCrit research and the connections to all the steps of my research. Chapter 5 provides my discussion, implications, and recommendations for future studies.

Chapter 2

Literature Review

Equity in STEM degree attainment rates has been a goal of policymakers and educational leaders since the 1990s. Often, this goal is made more palatable to policymakers by framing diversity as critical to increasing the economic competitiveness of the U.S. Focusing on the angle of increasing diversity to benefit the U.S. economy is an example of interest convergence (Bell, 1980) and continues to reinforce structural racist and sexist policies and practices that prevent progress in STEM diversity efforts. My study explores the inclusion and persistence of Black college women in STEM fields through a critical framework. Viewed through a critical lens, the inclusion of individuals with a diversity of characteristics is important in improving social justice as well as expanding STEM research and development to serve the needs of a diverse population.

Even as progress is being made at attracting Black girls and women into STEM, as evidenced by improvements in K-12 recruitment and increases in degree attainment in several STEM subdisciplines (National Center for Science and Engineering Statistics, 2021), continued disparities in the persistence of Black college students in math-intensive STEM fields reflect barriers created by complex, multifaceted issues. Efforts to increase representation appears to be making a difference for some racial/ethnic minorities and women in many STEM subdisciplines, but Black women continue to be underrepresented. Researchers have posited a multitude of factors to explicate the reasons some populations continue to be underrepresented in STEM disciplines. In general, the factors that form one's science disposition and lead to the decision to enter and persist in

a STEM field represent an intertwining mix of factors that are both external and internal to students. These factors have been broadly grouped within literature into science identity, science self-efficacy, science utility, and science interest. Pioneering research by Bandura (1977), suggested that "the strength of people's convictions in their own effectiveness is likely to affect whether they will even try to cope with given situations" (p. 193). Since then, the link between STEM self-efficacy, self-efficacy related to science and math skills, and recruitment and retention in STEM disciplines has been well documented (Carpi et al., 2017; Lewis et al., 2017; Strayhorn, 2015; White et al., 2019) and a plethora of research supports the role of self-efficacy as a primary driver behind the decisions students make to enter and persist in higher education. To date, there remains a lack of nuanced information about Black women in math-intensive STEM subdisciplines and the role of STEM self-efficacy in the persistence of Black women in STEM disciplines.

Organization of the Literature Review

In this literature review, I will first explore macrolevel issues, such as historical racial stratification within educational systems in the United States. This literature is drawn from higher education scholarship focusing on racially minoritized groups in STEM. Much of it is informed by Critical Race Theory (CRT) perspectives, a perspective and theoretical framework that emphasizes the centrality of race and racism in U.S. educational systems. Secondly, I outline some of the main empirical findings related to degree completion, persistence, and retention among racially minoritized students in STEM. The empirical literature is mostly quantitative and not informed by a critical

perspective or theory. Qualitative literature is less present and is more often informed by critical or critical race perspectives. The purpose of the first section of this chapter is to provide a view of the broader context and history of racism in the United States. This large-scale context is important in understanding the current situation faced by Black women and Latinas in higher education and in math-intensive STEM subdisciplines. This broad view is followed by a second section focused on the four specific factors that form one's STEM disposition which leads to interest and retention in STEM subdisciplines. This literature informs the design of the structural equation model I will execute in my exercise in employing critical quant methods. Lastly, I provide a summary and limitations of the literature.

Part 1: Critical Perspectives of Race and Racism in STEM Education

In a broad sense, racial inequities in higher education must be situated within the larger sociopolitical context, especially if we are to work towards more equitable outcomes. As Ledesma and Calderon (2014) asserted, "the quest for educational justice and equitable treatment within postsecondary institutions should not be decoupled from the context, history, and sociocultural realities that produced the inequities and disparities in the first place" (p. 215). Inequitable access for Black and Latina/o/x students in the U.S. extends beyond higher education and has included "a variety of factors, including differential access to high-quality, well-resourced K-12 schools and selective colleges and universities; employment discrimination; segregated social and professional networks; and other forms of systemic privilege and discrimination based on race and ethnicity" (Carnevale et al., 2019, p. 2). Throughout U.S. society, Black and Latina/o/x

students are routinely denied access to resources and are devalued because of racial oppression and White supremacy (McGee, 2016).

Racially Minoritized Groups in STEM

STEM culture, with its individualistic, meritocratic, survival-of-the-fittest mentality, perpetuates and amplifies the idea that individuals are responsible for their own failure to thrive within systems and institutions that block their access. Within higher education and STEM disciplines are historical pedagogical holdovers including the goal of assimilation of racially and ethnically diverse students into Eurocentric ideas, rather than presenting material that resonates with diverse cultural dispositions (McGee, 2020; White et al., 2019). In this way, marginalized groups and othered bodies, those who are not White males, are directly excluded from accessing or contributing to science. These persistent inequities in access and a Eurocentric focus have created "educational debt" (Ladson-Billings, 2006) rather than a "racial achievement gap." This language moves the discourse away from perceived deficiencies in minoritized students and reframes the issue as a society replete with structural racism and sexism. Essentially, the structural inequalities reflected in STEM fields, and MECS subdisciplines, in the U.S. are rooted in the institutionalized racism and White supremacy that is part of the history and fabric of the United States. These unequal racial hierarchies manifest in the organization, culture, and structure of STEM disciplines which continue to block access for othered bodies. Students of Color have been heavily studied in STEM, but their experience, as Abrica (2022) argued, is not being studied in terms of experiences with race and racism.

Campus climate. Racism and the racial climate in the U.S. play out in the climate on college campuses as a confluence of both internal institutional factors, such as the legacy of racial exclusion and limited compositional diversity within higher education institutions (Lee et al., 2020), and external factors. The racial climate on campuses is significant to Black students who have been stereotyped as failing due to individual deficits (Davis & Museus, 2019). Rather than accepting the narrative of individual deficits as an explanation for the lower numbers of Black and Latina women and entering STEM fields, there should be a focus on the impact of campus climate, based on the higher success rate of historically black colleges and universities (HBCUs) in graduating racially minoritized students from STEM programs compared to predominantly White institutions (PWIs) (Estrada et al., 2016). This evidence indicates that the persistence of racially minoritized students in STEM disciplines is impacted by campus climate rather than individual deficits.

While students of all races and ethnicities are impacted by campus climate, underrepresented racial minority students (URMs), such as Black and Latino/a/x students, are impacted more by negative racial experiences on college campuses than their White or Asian counterparts (Chang et al., 2014; Harper & Hurtado, 2007). Affirmative action policies designed to increase the compositional diversity on campus may increase compositional diversity, defined as the proportional representation of racial and ethnic minorities, but this increase in compositional diversity is meaningless unless the interactions that occur are overall positive in nature. Representation in the form of compositional diversity both across campus and within individual STEM programs is

important, but representation is not sufficient in building positive campus climate (Rincón, 2020). Beyond seeing themselves represented by compositional diversity, minoritized students need to feel a sense of belonging. Strayhorn (2015) explored how a sense of belonging in classrooms and across college campuses increases persistence and student success. Sense of belonging is discussed further below as part of STEM disposition and STEM identity and is incorporated into my structural model.

Racist policies and practices in education. At a societal level, indirect mechanisms that uphold racism are found in the policies and practices in education. One of these mechanisms includes a push towards meritocracy in higher education admissions standards in which students are held to the same standards when they are not provided equal opportunities due to characteristics such as their race or gender. Prior to entry of students into higher education, racism impedes the progress of Black students who are faced with higher numbers of disciplinary actions and reduced access to enrichment opportunities and other educational resources. When other background factors such as socioeconomic status and school characteristics are controlled, Black girls are under-referred into gifted math and reading programs during their K-12 education (Grissom & Redding, 2016). These intersecting racial and gender penalties directly impact the ability of these students to enter higher education on equal footing and with the math and reading skills required to succeed in STEM disciplines.

Another racist mechanism is deficit-based stereotyping that leads to the "tracking" of students into lower-paying fields and poor academic counseling during both K-12 and postsecondary education (Carter, 2006). The overall impact of these policies and

practices lead to overrepresentation of Black students in remedial education courses and at community colleges (Cohen et al., 2014). While community colleges are a viable entry point for many middle-class students, lower SES students and those working towards a bachelor's degree in a STEM discipline persist at lower rates when they attend community colleges (Karabel, 1972; Wang, 2015). Additionally, inequitable funding to minority serving institutions (MSIs) restricts access to racial minority students who choose to attend these institutions. Racism is more commonly found in indirect and subtle forms, such as microaggressions, policies, and practices, than in overt ways (Solorzano et al., 2000) and should be addressed openly when revising and creating education policies and practices.

Part 2: Research on Racially Minoritized Groups in STEM

In this second section of the literature review, I outline some of the main empirical findings related to degree completion, persistence, and retention among racially minoritized students in STEM. The empirical literature is mostly quantitative and not informed by a critical perspective or theory. The goal of outlining empirical findings from traditional empirical studies of racially minoritized groups in STEM is to highlight their methodological focus and the limited engagement with race and racism, hence the need for more critical quantitative approaches that I describe in the next chapter of this dissertation.

The focus of STEM higher education literature is on factors that shape choice, persistence, degree completion, and other outcomes across populations and contexts. A major focus of this literature is STEM disposition and the factors that support or block

students' pathways into specific careers. Below, I summarize the primary factors explored in the extant literature as components of STEM disposition – identity, interest, utility, and self-efficacy.

STEM Disposition

A student's decision to choose between STEM and non-STEM pathways and their persistence to completion in a STEM discipline is heavily influenced by four variables - their interest in STEM, their perspective of the utility of their chosen path, their academic self-efficacy, and their academic identity (Alhadabi, 2021). I explored each of these four variables – STEM identity, STEM interest, STEM utility, and STEM self-efficacy – and how they impact persistence towards a STEM bachelor's degree. These variables are typically explored as characteristics of individuals without addressing historical and systemic racism. My study expanded this view by incorporating a critical lens.

STEM identity. STEM identity is one of four factors that form STEM disposition and has been approached from an intersectional perspective in at least one study of women of color (Rodriguez et al., 2017). Identity has been defined as both the way one positions themselves in relation to others and how one is positioned by others (i.e., peers and teachers). Within STEM, this identity can more specifically be based on an individual's self-perception as a specific type of person – a biologist, a computer scientist, an engineer, or other. In addition, individuals hold multiple identities which have different salience, depending on context (Gee, 2000). In general, identity theory has extensive roots across disciplinary fields, including education and psychology. According to Carlone and Johnson (2007), an individual's science identity includes their possession

of scientific knowledge, an ability to communicate effectively and publicly in the language of science, and a recognition of themself as a scientist. STEM identity goes beyond simply science identity because the acronym STEM encompasses disciplines and fields that are simultaneously overlapping and distinct. One commonality between STEM fields is mathematics. Mathematics is positioned and utilized differently in these fields, but arguably, mathematics experiences and confidence are the primary link across these fields.

Academic achievement and persistence in a chosen STEM field are strongly motivated by one's science identity and sense of belonging. White et al. (2019) built on Carlone's and Johnson's (2007) definition of science identity to address race when they espoused that the development of one's science identity is, in part, influenced by the perception of how others recognize one's racial group within scientific disciplines. White et al. (2019) hypothesized that the higher graduation rate for Black STEM students from HBCUs, compared to PWIs, is due, in part, to a higher degree of faculty interactions with students and increased racial representation among faculty. For Blacks and other students of color, racial identity is a more salient part of their overall identity than in White students (Walker & Syed, 2013). Additionally, Blacks and other students of color tend to place a higher value on the integration of their racial and academic identities (Walker & Syed, 2013).

In STEM courses in which most students are White or Asian, a lack of recognition and representation can cause Black students to experience tension related to their racial identity. This internal discord between one's science identity and one's racial

identity, leads to negative impacts on a student's sense of belonging (Strayhorn, 2008). At the secondary school level, there is evidence that building a sense of belonging in girls in mathematics courses is critical in their development of a mathematics identity (Darragh, 2013). Currently, there is limited evidence of how STEM sense of belonging operates to influence interest in STEM careers but there appears to be an indirect relationship, mediated by STEM attitude, in women while there are both direct and indirect relationships in men (Xu & Lastrapes, 2022). Based on Strayhorn's (2008) proposed relationship in which the discord between STEM identity and racial identity in minoritized individuals negatively impacts sense of belonging, I proposed in my model that sense of belonging is a mediator for STEM identity which also has its own direct relationship with an intent to major in a STEM discipline for Black and Latina women.

Barriers to identity formation and sense of belonging. Black women students in mathematics, engineering, and computer science college courses do not see themselves represented by peers or faculty who are highly identifiable to them. Courses in these areas are taught by a woefully low number of faculty of color (Pierszalowski et al., 2018) and do not often provide a sense of belonging based on the pedagogy used and culturally irrelevant material**.** Underrepresentation at both the peer and faculty levels is relevant because racial representation and recognition has been linked to formation of science identity (Malone & Barabino, 2009). Uncertainty about whether one fits in STEM fields is more common in underrepresented minority students (Syed et al., 2011) and the perception of a mismatch in fit can lead students to alter their career path (Lewis et al., 2017). Unfortunately, underrepresentation will continue to act as a barrier to formation of

science identity if the current disparity in racial diversity in STEM disciplines is maintained and Black women do not feel that they belong.

Another barrier to the formation of a science identity is racial microaggressions (RMAs) that occur at both campus and academic levels. RMAs, defined as brief and subtle slights or insults that are used to invalidate the worth of students of color (Sue et al., 2007), reduce students' sense of belonging (Lee et al., 2020) and, within STEM departments, negatively impact the development of a STEM identity. Rather than being explicit expressions of racism, these more subtle assaults, which are experienced disproportionately by Black students, reduce the formation of science identity in marginalized students, and increase attrition from STEM classes and programs (Carlone & Johnson, 2007).

A final piece of identity development in STEM literature is the overall climate and continuing stereotype threat experienced by students of color. The "chilly climate" described by Seymour and Hewitt (1997) is formed by a competitive atmosphere that rewards individual achievement over collaboration and in which faculty are largely disconnected from students. Within this "chilly climate," stereotype threats, based on deficit models in which Blacks are portrayed as academically inferior, abound (Perna et al., 2009). Stereotype threats influence interactions between Black students and their peers as well as between Black students and faculty. While much of the literature indicates that these interactions negatively influence the sense of belonging for Black women and therefore negatively impact the formation of a strong science identity, scholarship by Ebony McGee and others has expanded the literature around stereotype

threat (McGee, 2018; McGee & Martin, 2011). Specifically, they emphasized that racial stereotyping does not lead to uniform responses. Rather, stereotyping impacts cognitive function across a range in individuals (McGee & Martin, 2011). Additionally, there is evidence that instructors lower their expectations and provide more limited feedback for improvement to Black students due to biases against students who are stereotyped as being inferior (Solorzano et al., 2000). In this way, stereotype threat may impede the progress of Black and Latina/o/x students and disrupt their formation of a strong science identity, but the complexities of race and racism lead to variation in how individuals respond. As reflected in my proposed model, one's sense of belonging in STEM classes is, in part, formed through their STEM identity.

STEM interest. A second factor that forms one's STEM disposition is interest in STEM. Interest in an academic area such as STEM increases the amount of effort and level of commitment a student is willing to put forth to succeed. This is particularly relevant in STEM disciplines in which the amount of effort tends to be substantial. Hulleman and Harackiewicz (2009) and others have found that interest is a strong predictor of enrollment in STEM-related courses in high school students. In a path model analysis of 115 racial and ethnic minority college students with sensory, learning, and mental health disabilities, Dutta et al. (2015) found that STEM interest was a stronger predictor of persistence than academic milestone self-efficacy, social support, and outcome expectancy. Math and science courses are typically challenging courses that require substantial study time. Having an interest in the material assists students as it gives them the ability to push through challenging course material and adopt the

successful study habits that are critical to persisting in any STEM discipline. This factor may also be considered part of one's science identity as Hazari et al. (2013) proposed.

STEM utility. The third factor that builds STEM disposition, STEM utility, draws on the perception of the relevance and usefulness of STEM at both an individual level – how a student perceives STEM as helping them reach their goals – and at a larger societal level – whether a student finds value in STEM within the communities they identify with. Utility is one part of the psychological theory of expectancy-value in which the value of learning STEM concepts can be linked to four aspects: (a) attainment value, i.e., the importance of learning for an individual's identity; (b) intrinsic value, i.e., how enjoyable the task is; (c) utility value, i.e., the benefits of STEM concepts in real world applications for both an individual and the wider community; and (d) cost, i.e., the perceived cost associated with studying STEM (Alhadabi, 2021; Shin et al., 2016). Addressing the culture in STEM disciplines and helping students realize the communal value in fields such as biomedical science has been shown to increase motivation in individuals (Brown et al., 2015), but this factor appears have limited variability across racial groups and has been shown to be positively correlated with persistence in Latino/a/x students only (Gottlieb, 2018). Therefore, this factor, while part of STEM disposition, is not considered in the model in this study.

STEM self-efficacy. STEM self-efficacy, the final factor considered in STEM disposition, refers to the self-judgement students hold about their ability to succeed in math and science. Self-efficacy, the belief in one's ability, is critical in the persistence of students in STEM fields because self-efficacy has a greater impact on career and major

choice than actual ability (Betz & Hackett, 1983a; as cited by Bandura, 1997). STEM self-efficacy is a subclass of academic self-efficacy and has been operationalized as the extent of confidence students have in their ability to complete tasks related to mathematics and science (Bandura, 1977; Britner & Pajares, 2006; Mensah & Jackson, 2018). Strong STEM self-efficacy leads students towards goals, such as pursuing a STEM career, in addition to increasing academic outcomes in a reciprocal fashion, i.e., students with strong self-efficacy persist despite challenges and reach academic goals, and academic achievement, in turn, bolsters self-efficacy and supports persistence (Bandura, 1997; Parker et al., 2014; Valentine et al., 2004). Inherent in building STEM self-efficacy is the opportunity to engage in authentic experiences that allow students to form judgements about their capabilities to engage and succeed in STEM. Within college, these experiences take the form of undergraduate research opportunities, study abroad programs, and interactions with faculty. As students develop a sense of belonging through authentic scientific endeavors, their self-efficacy and view of themselves as scientists and mathematicians grows. Additionally, it has been shown that higher self-efficacy leads to persistence along a given path (Sakellariou & Fang, 2021; Usher & Pajares, 2008).

Identity and self-efficacy are not synonymous factors, rather they are linked and most likely iterative. Students who identify with a given academic area tend to possess self-efficacy in that academic area and students with high self-efficacy in an academic area, based on their perceived ability and confidence, also tend to develop an identity linking themselves to that vocation (Honicke & Broadbent, 2016). A connection between

self-efficacy and identity is reflected in my model in which self-efficacy acts as a mediator between STEM identity and intent to major in a STEM discipline. In summary, one's STEM identity is essentially how they view themselves in terms of being a scientist, whereas one's self-efficacy is whether they view themselves as being capable of success.

Part 3: Theories of Race or Racism in STEM Higher Education Literature

Copious previous quantitative research into students in STEM education has utilized student development frameworks such as social cognitive career theory (SCCT) (Gaston Gayles & Smith, 2018; Howard-Hamilton, 1997; Kurban & Cabrera, 2020b; Lent & Brown, 1996; Wang, 2013) which may be misguided because these theories do not necessarily reflect the sociocultural experiences of Black students, particularly Black women (Howard-Hamilton, 1997). Qualitative studies have also tended to focus on intervention strategies directed at improving the recruitment and retention of individuals, rather than addressing the environment. Essentially, frameworks addressing individuals are not the best fit when studying issues such as racism and sexism which are systemic issues.

Another dominant framework in the literature, Bronfenbrenner's ecological or bioecological model of human development (Bronfenbrenner, 1979; Bronfenbrenner & Morris, 2006), has been cited in research examining the effects of social networks on Black girls' educational trajectories, including in STEM fields (Davis-Maye & Perry, 2007; Grier & Boutakidis, 2018). While applying this more systemic view is admirable and provides some insight into the ways in which context plays a role in development,

these studies do not address the larger societal and systemic issues of racism and sexism that continue to plague Black women. Bronfenbrenner's framework is often cited by authors mentioning the role of context in shaping one's path without applying the framework in their analysis (Tudge et al., 2009).

Critical Race Theory offers an alternative perspective to the abundant social cognitive theories presented within STEM higher education literature. While some inroads have been made, the number of publications presenting a critical perspective in higher education remains limited (Wofford & Winkler, 2022). It has been suggested by Wofford and Winkler (2022) that the paucity of publications from a critical perspective reflects gatekeeping mechanisms by editorial boards and others who hold the power to control academic scholarship. This dissertation provided an avenue for disseminating critical scholarship involving an exploration of how reflexivity as a method can be used to map the tenets of CRT onto QuantCrit research. More specifically, the publicly available HSLS:09 dataset was used as part of this study to provide an example of how personal, methodological, and conceptual reflexivity can be used to map the tenets of Critical Race Theory (CRT) onto a QuantCrit study utilizing structural equation modeling.

Limitations of the Literature

Few empirical studies utilize critical quantitative intersectional approaches or QuantCrit in higher education or, even more specifically, in STEM higher education (Jang, 2018; López et al., 2018; Pearson et al., 2022a; Van Dusen et al., 2022). Additionally, much of the quantitative research that does exist utilizes weighted measures

which may artificially capture experiences of Black women and there is limited extant research exploring methodological issues associated with large, complex datasets such as the HSLS:09 dataset (Hahs-Vaughn, 2005). There is also a paucity of environmental studies of structural racism and sexism; those that exist are conceptual or abstract in nature. While Black women are included in aggregated works with Black men or in the larger category of underrepresented minority students, the number of research articles more narrowly focused on Black women in STEM is relatively minimal. A gap currently exists between the ideals of critical quantitative intersectionality or QuantCrit and published research. An overview of a sampling of recent literature at the intersection of critical race studies of Black women in undergraduate STEM programs is provided in Table 1. The literature presented in Table 1 illustrates the divide between a critical approach and quantitative methodologies by summarizing the predominant methodologies and theories informing research on Black college women in STEM disciplines. As a scholar-practitioner, this study was designed to help fill that gap by exploring ways that large, publicly available datasets may be used for research using a QuantCrit or CRQI lens.

In addition to the paucity of literature surrounding the intersectionality of Black women in STEM, there is limited scholarship that reveals how to conduct exemplar QuantCrit studies (Table 2) and no examples of how to use reflexivity throughout a QuantCrit study. Table 2 provides an inventory of QuantCrit papers in higher education published from 2013-2023, including whether each is conceptual or methodological

Table 1

Summary of Extant Literature from 2012-2022 Addressing Black College Women in STEM Fields

Author(s)	Methodology	Framework/theory	Key points
Charleston et al., 2014	Qualitative; phenomenological	Black Feminist Thought (BFT) and Critical Race Feminism (CRF)	Utilizes a focus group study of Black women in college computing science programs.
Dickens, Ellis, & Hall 2021	Qualitative; literature review	Not implicitly stated	Conceptual paper reviewing literature on the role of mentors for Black undergraduate women in STEM.
Ferguson & Martin-Dunlop, 2021	Qualitative	Cultural border crossing and resiliency	Case study approach to understand the persistence of underserved Black women who earned a terminal STEM degree.
Ireland et al., 2018	Qualitative; literature review	Intersectionality	Review includes STEM literature for both Black women and girls.
Johnson et al., 2019	Quantitative	Not implicitly stated	Black women college students were surveyed about hypothetical situations involving faculty of different races and genders to assess sense of belonging and allyship.
McGee & Bentley, 2017	Qualitative; phenomenological	Resilience	Uses a multiple case study approach to address how institutions can improve the experience of high-achieving Black women in STEM.
Nguyen et al., 2021	Qualitative; interviews and focus groups	BFT	A multi-case study approach was used to explore the experiences of Black women in STEM programs at HBCUs
Stitt & Happel-Parkins, 2019	Qualitative; semi-structured life history interviews	BFT	Semi-structured life histories were used to gather data from Black women in engineering; analyses were intersectional and thematic.
Van Dusen et al., 2022	Quantitative	Critical Race Quantitative Intersectionality (CRQI)	Exploration of the impact of educational debt in Black women, created by society and maintained by introductory college courses.

Table 2

Summary of Extant QuantCrit and CRQI Higher Education Literature from 2013-2023

Author(s)	Conceptual/Methodological or Empirical	Evidence of Reflexivity
Castillo & Gillborn, 2022	Conceptual/methodological	No explicit evidence of reflexivity.
Covarrubias & Vélez, 2013	Conceptual/methodological	No explicit evidence of reflexivity.
Covarrubias et al., 2018	Conceptual/Methodological Research questions: 1. How can Critical Race Quantitative Intersectionality (CRQI) incorporate *testimonios* that are intersectional and transformational? 2. How do our particular educational *testimonios* help expand our analyses of the educational pipeline as a conceptual and methodological tool?	Throughout in the form of *testimonios*, primarily.
Gillborn et al., 2018	Conceptual/Methodological	No explicit evidence of reflexivity.
López et al., 2018	Empirical Hypotheses: 1. We expect there will be race–class gaps in graduation rates whereby black, American Indian, and Hispanic women and men in the same class status will have lower graduation rates than their white and Asian counterparts in the same class status as measured by family income. 2. We expect that there will be a race–gender gap in graduation rates whereby men and women in the same racial and ethnic group will have different graduation rates. Specifically, women in each group will have higher graduation rates than men at the low- and high-income quartiles. 3. We expect that black, American Indian, and Hispanic women will have lower graduation rates and higher levels of placement in developmental classes than white and Asian women.	Reflexivity was provided in explicit positionality statements. Implicit reflexivity in descriptions of choices made in methods.

Table 2 continues

Author(s)	Conceptual/Methodological or Empirical	Evidence of Reflexivity
López et al., 2018 (cont'd)	4. We expect that black, American Indian, Hispanic men will have lower graduation rates and higher levels of placement in developmental classes than white and Asian men.	
Nissen et al., 2021	Empirical Research questions: 1. To what extent have sexism, racism, and classism created educational debts of biology knowledge that society owes students before taking introductory college biology courses? 2. To what extent do introductory college biology courses mitigate, perpetuate, or exacerbate the educational debts that society owes students? 3. How, if at all, does the intersection of sexism, racism, and classism relate to society's educational debts before instruction and after instruction?	Reflexivity was provided in explicit positionality statements.
Park et al., 2020	Empirical Research questions: 1. What are the direct and indirect relationships between key background (e.g., identifying as Black) and college experience variables, student–faculty interaction, racial discrimination from faculty, and college GPA among undergraduate students in STEM? 2. Does racial discrimination from faculty mediate the relationship between student–faculty interaction and college GPA in STEM? 3. Do these pathways between variables differ for students of different race/ethnicities?	No explicit evidence of reflexivity.
Pearson et al., 2022	Conceptual/Methodological	Provides reflexive questions for use in QuantCrit research.
Suzuki et al., 2021	Conceptual/Methodological	No explicit evidence of reflexivity.

Table 2 continues

Author(s)	Conceptual/Methodological or Empirical	Evidence of Reflexivity
Van Dusen et al., 2022	Empirical Research questions: 1. To what extent have sexism and racism created educational debts of chemistry knowledge that society owes students before taking introductory college chemistry courses? 2. To what extent do introductory college chemistry courses mitigate, perpetuate, or exacerbate the educational debts that society owes students?	Reflexivity was provided in explicit positionality statements.

versus empirical in nature. Furthermore, I have indicated the extent to which each paper reveals evidence of reflexivity. Common across the QuantCrit research cited in Table 2 is the inclusion of explicit positionality statements. A recent survey of engineering education journal articles (Hampton et al., 2021) found only 15 works that included positionality statements. All 15 works were qualitative studies, indicating a gap within engineering education research. None of the papers cited in Table 2 used reflexivity as a tool to explore the experience as a researcher conducting a QuantCrit study. Notably absent are reflections of lessons learned through the researchers' experience. While positionality statements that include information about our relational positioning in society based on our gender, race, and class and allow us to openly engage with our beliefs and values, there is a need to go beyond polished positionality statements. Reflexivity can be used as a mechanism that allows transformative action through the process of *praxis* (Freire, 2000) to change the status quo. I propose that exemplar critical scholarship, including QuantCrit scholarship, should engage in reflexivity and, more importantly, be transparent by sharing reflexive thoughts in that scholarship. For researchers holding majoritarian beliefs, such as myself, being transparent about our own

shortcomings in our research, allows us to firstly, recognize how we uphold the status quo, and secondly, formulate analytical approaches that help reinvent our ways of knowing.

Chapter Summary

This literature review presented broad-reaching background information relating to race and racism in the U.S., specifically within higher education and STEM programs. Principle components within extant literature surrounding racially minoritized individuals in STEM – microaggressions, a "chilly climate," and sense of belonging – were highlighted. Additionally, key components of STEM disposition that have been explored extensively in extant literature – self-efficacy, identity, utility, and interest – were explored. My conceptual framework was elucidated and linked to the factors within my proposed structural equation model. Limitations within extant literature were explored, with an emphasis on the divide between quantitative and critical scholarship on Black college women in STEM fields. Furthermore, gaps in QuantCrit literature were emphasized. The next chapter will explore the methodologies used to answer my research question and articulate how I specifically explored the question of how to study Black women pursuing STEM fields and the viability of using QuantCrit methods in education.

Chapter 3

Theory and Method

The lack of progress in increasing representation of racially minoritized individuals in math-intensive STEM disciplines after years of focus on the assets and perceived deficiencies of minoritized individuals clearly indicates that the underlying issues do not lie with individual students. Instead, the issues are systemic and increasing representation of Black women and other minoritized individuals in STEM require disruption of these oppressive systems. Throughout this dissertation, I used the politically charged terms "race" and "racism" rather than semantic substitutes as part of a critical analysis. These terms were used with intentionality because colorblind and race-neutral explanations for inequities in STEM allow "racism without racists" (Bonilla-Silva, 2003) and the persistence of White supremacy (White et al., 2019). When discussing Black women in STEM higher education, there is a need to address the "permanency of racism while still working to create a set of strategic approaches for improving the plight of historically excluded groups" (Harper et al., 2009, p. 492). Outdated, mainstream interpretations have put blame, intentionally and unintentionally, on Black women by framing the persistent, unequal outcomes associated with race and gender in STEM fields as deficiencies in Black women. To counter this narrative, I approached my research with a critical lens and contextualized the intersection of race, gender, and STEM disposition in higher education. My study was designed to reflexively explore how the guiding tenets of critical quantitative methods work when used in critical quantitative studies of racially minoritized subpopulations with publicly available datasets and commonly used

statistical approaches. STEM self-efficacy, STEM identity, and sense of belonging were examined because of their prominent role within extant literature and because racism and sexism influence these internal constructs.

Part 1: Critical Race Theory

As previously noted, there is an abundance of higher education STEM scholarship utilizing social cognitive and human development frameworks (Grier & Boutakidis, 2018; Lent & Brown, 1996; Wang, 2013). There is also a rich body of qualitative work exploring the recruitment and retention of minoritized individuals in STEM education (King & Pringle, 2019; Lane, 2016). However, there remains a need for critical race frameworks in the literature on STEM higher education (McGee, 2020).

Critical Race Theory (CRT), an interdisciplinary, anti-oppressive theory, was initially established by legal scholars – Derrick Bell, Kimberlé Crenshaw, Richard Delgado, Alan Freeman, Angela Harris, Charles Lawrence, Mari Matsuda, and Patricia Williams – in the 1970s in response to stalled efforts to address racial inequities after the Civil Rights Movement (Delgado & Stefancic, 2023; Gillborn & Ladson-Billings, 2019). Since its inception within legal studies, CRT rapidly disseminated into social science research, particularly education. Within education scholarship, the use of CRT was pioneered by Gloria Ladson-Billings, William Tate IV, and Daniel Solórzano (Delgado & Stefancic, 2023) as a way to recognize and offer solutions to remedy inequities in education due to racism. Central to CRT is the concept of race as a social construct which, like racism, is fluid and complex, but leads to hierarchical relationships within U.S. society that favors White, heterosexual men above all others.

While there is no single definition of the framework of CRT, there are commonalities in the tenets or elements within CRT literature with an early definition of the following six tenets laid out by some of the early legal scholars involved in the development of CRT (Lawrence et al., 1993):

Tenet 1: Racism is Endemic in the U.S.

Racism operates routinely through systems that enable Whites to maintain power and preferential access to resources.

Tenet 2: The dominant legal claims of neutrality, objectivity, color-blindness, and meritocracy mask the interests of society's elites.

Racial realities are ignored or denied while emphasis is placed on merit even in the face of unequal distribution of resources which ensures the playing field is not level for all.

Tenet 3: Law must be analyzed from a contextual/historical viewpoint.

This tenet is also referred to as the "interest-convergence" principle in which advances for racially minoritized groups only occurs when White elites benefit (Bell, 1980).

Tenet 4: There is value in the experiential knowledge and narratives of people of color.

Experiencing racial domination from the position of a minoritized individual provides a unique perspective and voice that leads to questioning of assumptions within a majoritarian framework. This tenet is of significant value when discussing the use of statistics within traditional quantitative studies because, in the absence of a critical lens, statistical methods tend to reinforce racism.

Tenet 5: CRT is both interdisciplinary and intersectional.

Crenshaw, one of the leading legal scholars in the development of CRT scholarship, is also credited with coining the term "intersectionality" (Gillborn & Ladson-Billings, 2019) and highlighting the connection between the oppressive structures of racism and patriarchy.

Tenet 6: CRT works broadly towards ending all forms of oppression.

CRT has spread across social science disciplines and is used to work towards ending oppression and inequality linked to race, gender, class, sexuality, and dis/ability (i.e., *LatCrit, DisCrit, QueerCrit, AsianCrit*).

Part 2: Critical Race Quantitative Intersectionality (CRQI)

Born out of critical race theory (CRT) is critical race quantitative intersectionality (CRQI) (Covarrubias & Vélez, 2013) and a quantitative critical approach. While CRT in its truest form addresses the social constructs of race and racism, numerous offshoots addressing oppression on the basis of minoritized social identities and the intersections of these identities.CRT is broadly defined as a lens that can be used to view oppressive practices within institutions, discourse, and education (Garcia & Mayorga, 2018). The tenets of CRT have been modified and refined for use in QuantCrit scholarship. A quantitative critical (QuantCrit) approach in education utilizes five signature elements, or tenets, to allow statistics – historically used to marginalize racial minorities – to be used as a tool for exposing and dismantling racist and oppressive systems. These tenets, outlined in foundational articles (Garcia et al., 2018; Gillborn et al., 2018) and outlined below, play a role in QuantCrit research from the formation of research questions to the

analysis and presentation of findings (Suzuki et al., 2021). Embedded within the descriptions of each of the five tenets, I explain how a QuantCrit approach is juxtaposed against a traditional, non-critical quantitative approach. In this study, I will focus my efforts on exploring each of the tenets through reflexivity during each stage of my research. The tenets of QuantCrit are:

Tenet 1: The centrality of race and oppression.

Delgado and Stefancic (1998) posited that racism is a permanent facet of life. Because of the environment in which researchers exist, researchers, including statisticians, must reflect on their positionality and address biases that could inadvertently legitimatize inequities resulting from the systemic disadvantaging of students who do not identify as white, heterosexual, middle-class males. Traditional, non-critical quantitative methods do not account for racist and sexist power structures or the role of researchers' positionalities in upholding these inequities. By stating upfront that inequities are the result of racism, sexism, and/or classism, we can focus on identifying and disrupting the mechanisms that result in inequities.

Tenet 2: Numbers are not neutral.

Often presented as objective and neutral, QuantCrit scholars posit that numbers are no less objective than qualitative interpretations. Statistics and a mistaken belief that a reliance on numbers indicates objectivity have been used to advance racist ideas (McGee, 2020). QuantCrit pushes back on the idea of numbers as neutral tools. Rather, the research questions asked, the data collected, and the manner in which data are analyzed and interpreted are biased by researchers (Suzuki et al., 2021). Essentially, QuantCrit

scholars shun the idea of neutral researchers uncovering objective truths. As opposed to QuantCrit research, a positivist or post-positivist paradigm in which researchers are objectively observing the world drives most traditional quantitative research. While both critical and non-critical quantitative methods operate within an ontology in which reality exists outside of the mind, QuantCrit views this reality as being historically constructed (Lincoln et al., 2018).

In addition to addressing the lack of objectivity in statistics, it is critical to recognize that the use of statistics in QuantCrit research creates tension due to the potential mismatch between criticalist and positivistic epistemologies. Whereas the positivistic or post-positivistic epistemology driving quantitative research is focused on the majority and generalizations, a criticalist epistemology is focused on the outliers, the underrepresented minorities. The issue of dissimilar epistemologies has been resolved by repositioning who is centered and who is considered an outlier by not comparing minoritized students to the traditional norm of White, middle-classes students (Hernández, 2015).

Tenet 3: Categories of race and gender are not natural.

Race is a social construct, based on superficial characteristics, and is not a natural, biological category. The meaning people attach to superficial characteristics of different "races" is socially constructed and reflect racialized experiences. Binary gender categories are also socially constructed and fail to capture all gendered experiences. A QuantCrit perspective requires critical evaluation of the units of analysis. Within non-

critical research, race and gender are treated as given categories and background variables.

Tenet 4: Data cannot "speak for itself."

The collection and analysis of data should incorporate the voices of the people studied. Social science data is processed by people and reflects the personal biases of researchers. QuantCrit work relies on incorporating the voices of marginalized individuals. Research is done *with* marginalized groups, not *on* marginalized groups. There must be intentionality in incorporating voices in quantitative research by including insight gleaned through scholarship of marginalized individuals, at a minimum.

Tenet 5: Using numbers for social justice.

Historically, statistics played a central role in maintaining the status quo of racial oppression. Within a QuantCrit approach, the goal of using statistics is social justice and an equitable society. Statistics are seen as a tool that lacks inherent value. Within traditional, non-critical educational research, White middle-class males – the most privileged group - are considered the normative group against which others are compared. This normalization of privilege is an act of oppression and reinforces White supremacy and racial hierarchies. Rather than relying on between group comparisons, within QuantCrit studies, there is a noticeable and intentional lack of comparisons between racial groups. QuantCrit also challenges the deficit rhetoric commonly found in traditional studies that refer to students as "at-risk" or "disadvantaged."

CRQI is an approach that builds on QuantCrit to incorporate an intersectional perspective. CRQI was initially defined by Covarrubias and Vélez (2013) as:

> an explanatory framework and methodological approach that utilizes quantitative methods to account for the material impact of race and racism at its intersection with other forms of subordination and works towards identifying and challenging oppression at this intersection in hopes of achieving social justice for students of color, their families, and their communities. (p. 276)

CRQI is rooted within critical race theory (CRT) (Ladson-Billings & Tate, 1995) and intersectionality (Cole, 2009; Collins, 1990; Crenshaw, 1991). CRT and Critical Race (CR) scholarship in higher education provide a lens through which to view how hierarchical structures within U.S. society have been created by racism, which is defined as the oppression or privileging of people based on their perceived race (Ledesma & Calderon, 2014). CRT is an extension of legal discourse surrounding civil rights and racial reform as part of Critical Legal Studies which arose during the 1970s in the U.S. in response to slow progress in reaching racial equity (Delgado & Stefancic, 1998; Ladson-Billings, 1998). Using a CRT lens allows us to link the history and context of racism in the U.S. with educational outcomes and, more precisely, in this study, the development of STEM self-efficacy, sense of belonging, and STEM identity in Black college women. In this study, CRT is used as a means to better understand the racialized experience and the implicit role higher education institutions and STEM disciplines have played in upholding and maintaining oppression of Black people (Ladson-Billings & Tate, 1995; White et al., 2019). As an extension of CRT, CRQI provides a parsimonious framework that uses the lens of a critical theoretical perspective to contextualize the intersectional, racialized, and gendered experiences of Black women in STEM education in the sociopolitical environment of the United States and is motivated by a desire for equity and social justice. Specifically, this study drew on a critical quantitative analysis and

scholarship on Black women to consider the utility of large-scale datasets, such as the HSLS:09 dataset, in examining the experiences and outcomes for Black women in STEM higher education.

CRQI is guided by the following principles (Gillborn et al., 2018; Van Dusen et al., 2022), summarized succinctly as:

1. the centrality of oppression;
2. categories of race and gender are neither 'natural' nor given;
3. numbers are not neutral and data cannot 'speak for itself,' researchers must provide the voice and interpretation; and
4. the importance of intersectionality.

In practice, the principles of CRQI, as addressed in this study, involve utilizing the outlined principles of CRQI to allow numbers to work towards social justice for Black women in STEM in the following ways:

1. The centrality of racism and sexism in the U.S. are addressed by recognizing and calling out the oppressive systems that lead to and maintain educational inequities in marginalized students. As part of this principle, I will expressly examine how educational debt has led to the inequities seen in Black college women in STEM courses.
2. The categories of "Black," "Latina," and "women" are socially constructed categories. My model aggregates students based on these socially constructed categories and reflects the power structures within U.S. society that created them.

3. Racist and sexist assumptions drive all stages of research through the development of a study through the analysis of data and conclusions drawn. Working with small sample sizes may preclude the use of *p*-values and require a shift to using standard errors as a way to inform confidence in results (Van Dusen et al., 2022).
4. Intersectionality is important because the way Black women experience the world is unique from the experiences of Black men or women of other races and ethnicities. Rather than examining race or gender separately, this study focuses on the intersection of these two socially constructed categories.

With these principles in mind, quantitative CR researchers must continually engage with the legacy of White supremacy and racism that are part of the history of social science research (Bonilla-Silva & Zuberi, 2008; Covarrubias & Vélez, 2013). In this study, race was addressed as a social construct and anchored within the historical context of racism in the United States. Additionally, it is imperative to remember that the logic, viewpoints, and biases of researchers are embedded within statistical analyses. Rather than numbers being neutral, statistics involve numbers that are interpreted and presented by researchers who possess their own biases and viewpoints.

The prevalence of numbers and quantitative approaches utilizing large-scale datasets to justify and shape educational policies points to the need for researchers to resolve how to incorporate a critical race-conscious framework into quantitative methods. Without this shift in perspective, existing race inequities will continue to be normalized and disguised. Rather than rejecting quantitative approaches and shunning the use of

statistics, critical quantitative scholarship should be used to expose dominant assumptions that create inequities and work towards using the language of numbers, a language policymakers tend to fixate on as superior, to promote social justice. CRQI, in conjunction with CR qualitative scholarship, allows engagement with racialized and gendered inequities and provides a path towards social justice. In this dissertation, my focus was on how I, as a White woman, could engage reflexively with the tenets of CRQI scholarship within quantitative research.

Quantitative methods have been shunned by critical theorists due to the historical use of statistical logic in supporting racial and sexist agendas (Bonilla-Silva & Zuberi, 2008; Cokley & Awad, 2013). Because of this history, as part of utilizing the framework of CRQI, it is critical to provide an evaluation of the strengths and weaknesses inherent in using quantitative methods in research involving minoritized peoples. One critique of using quantitative data is that enumeration of data based on social constructs of race and gender is crudely homogenizing. Nuanced diversity and privileging of certain individuals within a given social group are lost in this homogenizing process and qualitative approaches are better suited for understanding the nuances, but as Gillborn et al. (2018) posited, quantitative approaches are "well placed to chart the wider structures . . . and to highlight the structural barriers and inequalities that differently racialized groups must navigate" (p. 160). I argue that the use of quantitative data in CRT work is appropriate, depending on the research questions and the way in which the data is analyzed and used.

Another critique of quantitative work that has been made is that statistics were developed to support racist values and to uphold a racist status quo. Like other research

tools, statistics lack inherent value and, by themselves, are not racist or sexist. Rather, research methods and data analysis are driven by the values, analysis, and interpretation of researchers. As Covarrubias and Vélez (2013) delineated, “numbers are given voice largely by the theoretical underpinnings upon which they rest.” Reflexivity and thoughtful presentation of one’s positionality, as is more commonly done with qualitative research, is a critical component in a CRQI approach and is, therefore, part of my methodology used to explore how the tenets of CRQI can be applied within a quantitative study.

In summary, a QuantCrit perspective and the framework of CRQI guided the research question and shaped the study in several specific ways. There was intentionality in reviewing critical scholarship by Black women (Collins, 1990; McGee, 2020) in addition to scholarship created by other minoritized individuals (Covarrubias et al., 2019; Gillborn et al., 2018) to gain insight into anti-oppressive research. The framework of CRQI informed the research design regarding the choice of variables and the methods used for analysis and interpretation of the data. To reiterate, the main purpose of this dissertation was to reflexively explore and understand how to apply critical quantitative approaches in studies of racially minoritized students in STEM higher education research.

Part 3: Positionality

Exploring one’s biases and stating one’s positionality upfront allows readers to evaluate the objectivity of the researcher who acts as the research instrument. While positionality statements are more commonly used in qualitative research, there is a push to include positionality statements in critical research (Patrick et al., 2022) and the

framework used in my dissertation was centered around Critical Race Theory. Guiding this research are two important ways in which my positionality informs my approach. I identify as a White woman who was raised in a metropolitan city in the southern U.S. Professionally, I hold a master's degree in biology and have been teaching biology courses at a rural, Midwestern community college for 16 years. Growing up, I had regular contact with individuals who were situated as "others" in terms of socioeconomic status, race, ethnicity, religion, and sexuality. I was socialized to help, but not necessarily learn from, those who were "othered." I approached this study as a scholar-practitioner, drawn to researching underrepresented STEM students based on my own experiences as a woman within STEM education and a desire to increase social justice and equity.

From the beginning of my doctoral program studies, I have grappled with narrowing my research interests surrounding underrepresented STEM students because I have had concerns about my ability to accurately capture and explore the experience of underrepresented students who have had different life experiences than my own. I have also been met with two different pathways or approaches within my graduate studies. The first pathway is a critical paradigm emphasizing racialized experiences but methodological training emphasizing quantitative approaches and theories that explain. For example, during my review of literature, I read through many studies that utilized a social cognitive career theory (SCCT) framework and I questioned the lack of incorporating race and racism in these individual-level decisions accounted for in this framework. On the other hand, in my readings of more critical qualitative studies of Black women in STEM, I contemplated how these experiences could be documented

quantitatively and whether relevant frameworks exist. Thus, this study began with both a methodological and theoretical questioning on my part and me wanting to push White women in STEM to be thoughtful about race and racism through focusing on racially minoritized students.

Essentially, I am a White woman seeking to use methods and theories that resonate with me (in the sense that these have been emphasized in my doctoral training) while also wanting to do justice to what are inherently racialized experiences among Black women in STEM. At the heart of this dissertation is a desire to join critical, race-centralizing approaches, theories, and methods with what I have observed in STEM literature while focusing on quantitative models and predictive outcomes. I have wondered whether critical, race-centralizing approaches and quantitative methods are reconcilable, and this research allowed me the opportunity to explore the possibilities and limitations. In my dissertation, I stepped outside of what is comfortable to explore that reconciliation and the possibilities for using race-focused approaches in a critical quantitative study using a large-scale dataset.

Part 4: Reflexivity as Method

This dissertation used the method of reflexivity to answer the questions around how to do critical quantitative methods using commonly used data sets and quantitative approaches, specifically structural equation modeling. A method in research is an approach that allows the researcher to answer stated research questions, and by answering those questions, ultimately, fulfill the purpose of the study. My stated purpose in this study is to explore and understand how to apply a QuantCrit approach to the study of

racially minoritized students in STEM higher education. The method of reflexivity was chosen as a vehicle to explore the possibilities and the limitations of both a QuantCrit study using a large data set and myself, as an emerging QuantCrit researcher. Reflexivity has been defined as a way to "scaffold critical thinking in order to make visible some of the connections between research questions and research conclusions, and open the way to critically different interpretations" (Lazard & McAvoy, 2020, p. 160) and as a "set of continuous, collaborative, and multifaceted practices through which researchers self-consciously critique, appraise, and evaluate how their subjectivity and context influence the research process" (Olmos-Vega et al., 2022, p. 2). These definitions reflect the value inherent in addressing the subjectivity in research but finding concrete examples of how to apply reflexivity in a study reveals ambiguity in application. I clearly delineated my own procedures – the questions I asked and how I incorporated reflexivity throughout my dissertation.

There are multiple definitions of types of reflexivity within reflexivity literature (Olmos-Vega et al., 2022; Schwandt & Gates, 2018). Rather than restricting myself to a single type, I explored a mix of **personal, methodological, and contextual reflexivity** (Olmos-Vega et al., 2022). Personal reflexivity provided a way to explore the impact of my research on myself in addition to how my own motivations and prior experiences impacted my research. More specifically, I explored my role as a research instrument, how power differentials play out in knowledge production, and my own limitations as a White woman researching Women of Color. Methodological reflexivity was used to explore how my paradigm, my worldview, impacted my research decisions and

interpretations. Contextual reflexivity was used to situate my study historically and culturally. These types of reflexivity, together, allowed me a qualitative way to reflect on each of the five tenets of QuantCrit research and how they relate to each component of my research project.

As noted in the literature review, there are copious examples of quantitative literature in STEM higher education, but these, as critical scholars have argued, do not account for whiteness and White supremacy (Delgado & Stefancic, 2023; Gillborn et al., 2018; McGee, 2020) which are the heart of CRT and a QuantCrit perspective. Throughout this study, I used personal, methodological, and contextual reflexivity to explore the possibilities and constraints associated with QuantCrit research. To achieve this, I maintained a research journal (Nadin & Cassell, 2006) which allows "in-depth thinking about the methods we use and the epistemological commitments that underlie them" (p. 209). My research journal was a simple lined notebook in which I recorded handwritten reflections. Entries were made prior to, during, and after working with the HSLS:09 dataset; these entries included my reflections on the questions presented in Table 3. My research journal allowed me to explore methodological issues as well as my own values and beliefs as a researcher. Castillo and Gillborn (2022) provided guidance on practices to follow and questions to ask when performing QuantCrit research and their suggested questions formed the basis of the reflection questions I answered in my research journal (Table 3).

Table 3

Summary of Reflexive Practices and Questions, Tied to the Tenets of QuantCrit Research

Reflexivity Practice	Tenet	Reflection Questions	Most Relevant Stage(s) in Research Process
Personal	Tenet 1: Racism and sexism are permanent facets.	What is my background? What assumptions might I bring into my research? How might my identities influence my research? Why am I conducting this research? Who will benefit?	Positionality statement, research design, findings, and conclusions
	Tenet 4: Data does not "speak for itself."	How can I ensure my representation resonates with women of color and not my own majority beliefs?	Literature review, findings, conclusions
	Tenet 5: Numbers should be used for social justice.	How am I addressing my personal biases and limitations?	Positionality statement, conclusion
Methodological	Tenet 2: Numbers are not neutral.	Who was/was not included? When and how was the data collected?	Reviewing HSLS:09 data and choosing appropriate variables
	Tenet 3: Categories of race and gender are constructed.	How are the racial and gender categories defined? Do the groupings used accurately represent the categories being presented?	Reviewing HSLS:09 data
	Tenet 4: Data does not "speak for itself."	How is my research agenda influenced by the voices of women of color? How can I ensure my representation resonates with women of color and not my own majority beliefs?	Literature review, findings, conclusions
	Tenet 5: Numbers should be used for social justice.	Are survey items worded from a deficit- or asset-based perspective? Are survey items culturally responsive to the population being studied?	Reviewing HSLS:09 survey items
		How am I using language throughout my study?	Entire write-up

Table 3 continues

Reflexivity Practice	Tenet	Reflection Questions	Most Relevant Stage(s) in Research Process
Conceptual	Tenet 1: Racism and sexism are permanent facets.	Should research be restricted to people we identify with?	Findings and conclusion
	Tenet 4: Data does not "speak for itself."	Should we study individuals we do not identify as? If so, how?	Findings, conclusions
	Tenet 5: Numbers should be used for social justice.	Are my results presented from an anti-oppressive perspective?	Findings, conclusions

Within my writing, reflexivity is displayed throughout my dissertation. The use of reflexivity led to fluidity and flexibility within my study rather than maintaining rigid research questions that are stated upfront and do not change during a traditional quantitative study (Olmos-Vega et al., 2022). Within my positionality statement, I addressed my paradigmatic stance as part of personal reflexivity. The language used throughout my dissertation was aligned and reflected my paradigmatic stance. My Methods section included how my perspective impacted my study (personal reflexivity), how my paradigm impacted my research decisions and procedures (methodological reflexivity), and how I sought to explore the context and situate my study (contextual reflexivity). I clarified where the data came from in my Findings section and addressed how the data was interpreted as well as how the data was used. My Discussion and Conclusions provided an opportunity to reflect on my findings and situate my work within the literature. I also presented literature and aspects that may challenge my own interpretations.

Writing in the third person is commonly used as a method of presenting research as objective and outside of the researcher. This writing style reflects the positivist epistemology of the scientific method in which I was formally trained prior to entering my doctorate education. A critical component of this study is the recognition that the context of a researcher and their positionality is important in allowing readers to consider how my identities and position play out in knowledge production. As part of my reflexive methodology, I relied on a first-person narrative to make my role as the researcher explicit (Lazard & McAvoy, 2020). The use of first-person writing in my research journal is reflected within my findings and conclusions.

Because one can only be reflexive to a certain point on one's own through internal dialogue, I relied on supervision and debriefing with others, primarily my graduate advisor, Dr. Abrica, as this external dialogue brings clarity and reduces the tendency of reflexivity to become narcissistic (Probst, 2015). Additionally, I performed reflexivity while exploring the scholarship of People of Color, especially Women of Color, and I was receptive to understanding why White scholars attempting to become critical race theorists is yet another form of colonization (Bergerson, 2003). While I am not trying to relay the experiences of Black women or other Women of Color, I feel that I, as a White woman, should be listening to the voices of Women of Color and using my position to promote the strategic use of CRT tenets. At a minimum, I feel it is my responsibility to explore alternative methods and find ways to reduce or eliminate the harm that can come from statistical approaches.

Integrating Critical Race Theory with Quantitative Approaches: Using Reflexivity to Explore How to Study Women of Color in STEM

Prior to 2017, QuantCrit appeared in only four published studies and is still developing as a method (Castillo & Gillborn, 2022). This study weaved together reflexivity with a quantitative approach using a large national dataset to explore how QuantCrit can and should be utilized in practice. The overarching goal was to contribute to the discourse centering underserved and underrepresented students in STEM higher education by exploring potential methodological opportunities and issues with utilizing large, national, datasets. I approached this study from a critical perspective with the understanding that quantitative methods and statistics are steeped in White logic and ways of knowing (Bonilla-Silva & Zuberi, 2008). To address my own role as a research instrument through which this study was developed and conducted, reflexivity (Merriam & Tisdell, 2016; Yao & Vital, 2018) was used to explore my own perspective and ways of knowing. As a biologist, I entered higher education research with a background in traditional quantitative methods. As I began my journey in educational research, I became aware that the complexity and nuance of racialized experiences among People of Color are not captured when race is reduced to a background variable (Zuberi & Bonilla-Silva, 2008). The critical perspective of CRT resonated with me but I am also sensitive to the use of quantitative data by policymakers. As a White woman, I acknowledge that my race limits the ways in which I engage with CRT but I am drawn to incorporating the tenets of QuantCrit methods into quantitative research because I recognize that social justice will not be achieved unless we approach knowledge gathering from a critical perspective.

In this dissertation, I used reflexivity as a method to explore the viability of reconciling two divergent approaches to the study of Black women in STEM: one approach is a traditional area of STEM scholarship that largely uses nationally available data to examine established constructs like self-efficacy, sense of belonging, and identity and the relationships between constructs. The second approach is critical and qualitative in nature, focusing on intersecting forms of oppression as they shape experiences and outcomes for Black women in STEM. Through reflexivity, I aimed to explore and understand how Black women and other Women of Color, as demographic groups, can and should be studied in STEM higher education. This dissertation was a methodological study which used reflexivity as a method to explore the viability of studying Black women pursuing STEM fields using critical quantitative methods in education. Again, the extent to which I was able to weave together a CRQI tenets with a feasible, SEM model focused on Black women in STEM while using a publicly available dataset was the heart of this dissertation. In other words, I was not focused on the independent, empirical results of the SEM model to be produced. Rather, the reflexivity around the conceptual and methodological use of the tenets of a QuantCrit approach in the study of a minoritized population in STEM higher education is what I discuss in the findings chapter of this dissertation at length. To address how to study Black women in STEM, I engaged in a process of reflexivity about points of complementariness and points of divergence between the existing literature and my proposed SEM model.

Chapter Summary

Again, the purpose of this study was to explore the methodological pursuit of a quantitative critical (QuantCrit) study centering a racially minoritized subpopulation – Black and Latina women - within a national, publicly available dataset. To achieve this goal, I used reflexivity as a method while applying a QuantCrit approach to examine the relationship between Black and Latina women students' sense of belonging, STEM identity, and STEM self-efficacy in engineering, computer science, and math and their intent to obtain a bachelor's degree in a STEM field. While the quantitative approach uses structural equation modeling (SEM), the focus of this study is the reflexivity on the process of a QuantCrit or CRQI research approach - from data collection through the analysis and interpretation of the results - using a large data set. I reflexively explored how structural equation modeling using the HSLS:09 data set is or is not consistent with the tenets of QuantCrit and the use of a critical framework. This chapter begins with a positionality statement and a reiteration of my conceptual framework to ground my research methodology. Following the conceptual framework is an overview of the methodological approaches I used. This chapter outlines the details of the research design used in this study, including the methodology and analysis, a description of the data set, and the specific factors used to build constructs within my model. The conclusion of this chapter includes a summary of the overall design and methodology.

Chapter 4

Findings

Qualitative studies have been a mainstay of critical research into the power structures that impact the lived experiences of marginalized people due to racism and sexism. A relatively newer form of scholarship, QuantCrit, has been introduced as a way to utilize large-scale data sets and statistics to elucidate the inequities that reproduce social injustices within different aspects of society, including STEM higher education. I begin this chapter by reviewing the main elements, the central tenets, of a QuantCrit framework. For each tenet, I have included the reflexive questions I used to explore how the study I developed – from its conception through each stage of research – is or is not compatible with a QuantCrit study and whether I reached the goal of addressing oppression and its effects. Additionally, I used reflexivity more broadly to explore the feasibility of using critical quantitative methods to study Black women in STEM. Following this overview are more detailed descriptions of each stage of research completed during the SEM study utilizing the HSLS:09 data set.

Tenet 1: The centrality of oppression – racism, sexism, and classism.

Racist, sexist, and classist power structures in the U.S., not the socially constructed categories of race and gender, are behind the inequities seen across all aspects of life, including educational systems. Within education, these inequities are frequently referred to as "educational gaps," and blame is placed on oppressed individuals for perceived failure to reach the normative set by White males. These inequities should more appropriately be acknowledged as "educational debt" resulting

from oppression (Ladson-Billings, 2006). The salient points of oppression in this study for Black and Latina women in STEM higher education, are racism and sexism. Rather than discussing what is known – that racism and sexism are endemic in the U.S. – this tenet provides that the focus should be on the mechanisms behind these power structures. QuantCrit approaches research with the recognition of the centrality of oppression but, in my opinion, quantitative research by itself lacks the ability to provide a nuanced look at the mechanisms. Oppressive measures are not freely amenable to being quantified without the nuance provided by qualitative components.

I approached this study with racist and sexist power structures and the history of statistics as tools to reinforce social hierarchies in mind. As a middle-class White woman, I recognize my own positions of power – an elevated status based on my whiteness, and a lower status based on my gender, within the hierarchies of U.S. society. While I am able to relate to issues that impact women, I lack the lived intersectional experience of being a Black woman and my race limits the ways in which I can authentically engage with CRT. I am entering this space as a woman, recognizing that I must educate myself to better understand the experience of Black women who are further minoritized and disempowered because of socially constructed categories of race and racism.

Personal Reflexivity- What is my background? What assumptions might I bring into my research? How might my identities influence my research? Why am I conducting this research? Who will benefit?

My background is addressed in more detail in my positionality statement within Chapter 3 but, briefly, I identify as a White woman trained as a biologist and a

community college professor. My identities lead me to view the world through White ways of knowing. Additionally, my background as a research biologist was steeped in a post-positivist paradigm and the belief that statistics represent objective data. My previous research experiences as a biologist did not prepare me for the subjectivity and human interpretations that form the basis of social science research involving the complexities of human behaviors and actions. Prior to my years as an educational studies doctoral student, I was unaware of qualitative research methods and held biases against research methods that fell outside of traditional, quantitative methods. I had to grapple with reconciling my own research methods biases before I could understand how my own methods can uphold oppressive forces.

I conducted this research because I want to be part of an educational system and society that values and strives towards social justice. While this dissertation provides a methodological contribution, rather than truly advancing racial equity in a meaningful way, either through research specific to Black women or institutional practice, the goal of social justice is at the heart of my motivation for exploring QuantCrit as a method. This research was designed to indirectly benefit marginalized students interested in STEM and, more directly, help other researchers who are interested in CRQI and QuantCrit educational research. I engaged in this research as a way to expand the conversation around the methodologies we use to advance equitable outcomes in higher education. Expanding the use of reflexivity as a method and providing insight into my personal exploration of the experience of incorporating the tenets of CRQI while performing a

QuantCrit study in the field of STEM higher education was at the heart of this dissertation.

To achieve the goal of equity in STEM education, we must first operationalize equity in STEM education. I view equity in higher education as the "equity of parity" (Rodriguez et al., 2012) which is defined succinctly as students achieving the same average, post-instructionally, regardless of their starting point. This requires disproportionate resource allocation to address educational debt resulting from systemic racism and sexism. CR educational research should address the mechanisms required to ensure college students achieve the same goals despite systemic oppression which impacts the starting point for marginalized students. As a community college practitioner, I am intimately familiar with the need for disproportionate resource allocation for students to achieve equitable outcomes in science and math courses.

Conceptual Reflexivity - Should research be restricted to people we identify with?

Bonilla-Silva and Zuberi (2008) posit that Scholars of Color are best positioned to address racial stratification. While I agree that Scholars of Color are *best* positioned, I also believe that if we restrict research to only those we identify with, the labor of educating others will fall more heavily on those who are marginalized. Furthermore, if social science scholars restrict their research solely to those we identify with, I would expect gaps in research for individuals who are not well-represented. As suggested by Delgado and Stefancic (2023), "how to bridge the gap in thinking between persons of good will whose experiences, perspective, and backgrounds are radically different is a great challenge" (p. 47) but I feel we, as scholars, should strive to bridge the gap.

Additionally, because individuals have intersecting identities, we may find areas of overlap and commonalities even while we maintain distinct differences.

Those in positions of power should use their position to work with and provide a voice to othered individuals. As a White woman, I can use my position of privilege to inform my work with the tenets of CRT without becoming a critical race theorist and without attempting to be the voice of Women of Color. From a personal standpoint, I would not expect others to understand my own position as a White woman, but I believe people can empathize and listen to those who hold identities outside of their own. I can act as a research instrument when working with individuals who hold an identity other than my own. I can put in the work to learn about the experiences of others and I can, to the best of my ability, interpret data in a manner that resonates with those represented in a study. I believe we all play a role in questioning how statistics are used to marginalize Students and Scholars of Color and my own role is in challenging what have been normative practices. As a White scholar, I play a role in understanding that although race is not salient in my daily life, to ignore race and racism prevents me from addressing the policies and practices that perpetuate injustices (Bergerson, 2003).

By engaging in reflexivity and scholarship by People of Color, I hope to move beyond my own experiences as a White woman in STEM. I will continue to seek ways in which the tenets of CRT can inform not only my research, but also my practices in higher education and opportunities within my life – personally and professionally – in which I can question and engage in conversations about racist actions. It is my role to provide the transparency required for others to critique my methods and interpretations. As scholars,

it is our duty to act diligently in exploring our biases and learning about the individuals we study to ensure that we are not simply viewing issues through our own lens.

Tenet 2: Numbers are not neutral.

Hegemonic assumptions influence all aspects of research. No research findings – from either qualitative or quantitative research are neutral, objective facts. Instead, all research reflects researcher biases introduced during data collection, analysis, and interpretation. As researchers and consumers of research, it is our responsibility to center this lack of neutrality in our interpretations and sense-making. Potential biases should be made transparent in all forms of research, not only through positionality statements, but throughout our research to allow consumers to more easily identify those biases. Beyond the biases of individual researchers, there must be acknowledgement that because racism is deeply entrenched within our institutions, racism is reflected in data collected by those institutions and in research and reports.

Personal Reflexivity - How am I addressing my personal biases and limitations?

I have come to recognize the limits of a post-positivist paradigm, a paradigm I held as a biologist, but the limits of objectivity do not necessarily negate the use of quantitative methods. Instead, I recognize that I must explore my own biases and limitations because I am acting as a research instrument. I used reflexivity to explore my own limitations and biases in studying Black women in STEM disciplines. My primary limitation in this space is being a White woman. While I can educate myself and others on the tenets of CRT, to claim that my voice is representative of Black women or to claim myself as a critical race scholar would be, in my mind, appropriation. Throughout this

methodological exploration, I have provided reflexive responses within this dissertation as more than a simple positionality statement. I explored each aspect of the research process in addition to the tenets of CRT.

In addition to my limitation as a White woman, one of my personal limitations is that I find it difficult to be critical of others' work. I recognize that I must be critical, or I will simply be repeating the status quo that appears to be creating stagnation in STEM education literature, but I struggle with the tension of being critical of the ideas of more experienced scholars. I also struggle with the tension inherent in bringing criticality into STEM research which exists within a post-positivistic paradigm. Statistical theory and researchers using statistics, particularly those studying minoritized students, need to scrutinize their methods to uncover the ways in which racism is perpetuated. A more minor personal limitation within my study was an unrealized lack of awareness surrounding the decision I made to utilize a "sex" variable, a variable that indicated biological sex, instead of choosing a variable describing gender identity. I inadvertently conflated biological sex and gender identity.

Methodological Reflexivity - Who was/was not included? When and how was the data collected?

The HSLS:09 data set randomly sampled over 23,000 students who began high school in the U.S. in 2009 at 944 schools across 10 states. Sampling began in 2009 and was repeated when this cohort of high school freshmen would have been juniors and then seniors in high school. Sampling was also done after high school to capture the pathways students followed three and four years after the expected high school graduation date for

students remaining on track. This dataset captured a broad cross-section of individuals from different races, ethnicities, gender identities, socioeconomic statuses, and family structures.

Conceptual Reflexivity - ***Are systemic racism and sexism represented in the choice of variables? What information may have been omitted during data collection?***

As in most surveys, the hierarchies in society are reflected in the order of the response choices with "male" and "white" being the first options for biological sex and race, respectively. Information about students' identities – how they truly see themselves and how they are viewed in society – is omitted when information is gathered in survey questions. The complexities of human identities and the intersection of identities is omitted in the gathering of survey data by the simplifying nature of this type of data.

Tenet 3: Groups are not natural.

When groups or categories such as race are applied in research, they are not based on biological or scientific truths. More accurately, groups are based on social constructs that allow maintenance of oppressive power structures. Variation in scores across socially constructed groups, such as comparing Black men to White men when White men are considered the "norm," leads to common interpretations of the variation being ascribed to differences in the group membership (Arellano, 2022). Transparency must be used when aggregating data because groups are not natural, and groupings chosen should align with the categories presented in the research. Aggregating data should be minimized as much as possible to prevent erasure of the diversity and intersecting identities within students. Aggregating Black and Latina women into a single group of Students of Color to ensure a

large enough sample size for statistical analyses removes nuances and leads readers to infer that Black and Latina women share lived experiences. Further erasure of identity occurs when a few responses of individuals from underrepresented groups are weighted in large data sets. This weighting amplifies limited voices and artificially presents these limited responses as representative of a larger group as part of what Delgado and Stefancic (1998) referred to as essentialism. While all oppressed persons share oppression as a common occurrence, the experiences of individuals are as unique as the people living them. Reducing the voices of many to a select few, who may or may not share the same goals and strategies for mitigating oppression, leads to silencing voices.

Methodological Reflexivity - How are the racial and gender categories defined? Do the groupings used accurately represent the categories being presented?

The variables capturing information about how individuals identify, in terms of their race, ethnicity, gender, and biological sex treat individuals in a simplistic, dichotomizing manner. The categories defined in the survey questions matched with socially constructed categories. When responding to survey questions, individuals were forced to choose singular identities without options for those who are may identify as more than one race. The categories presented in the HSLS:09 data set represent the socially constructed categories presented in this study.

Tenet 4: Data does not "speak for itself."

Data is manufactured and interpreted through human decisions, not an innate quality embedded within data or numbers themselves. When researchers embody majority beliefs, the data created resonates with these beliefs. Within traditional statistical

analyses, normative groups are used as comparisons for marginalized individuals and groups. A normative group is chosen based on which group has the most privilege in society and the voices and ideas proposed as being shown by the data are most often associated with those who are privileged. In the U.S., the normative group used for comparison are middle-class and affluent White men. The normalization of privilege and perpetuation of White supremacy are acts of oppression. Rather than representing any truth uncovered in data, the normalization of privilege represents the subjectivity of human interpretations.

Embedded in the process of normalizing privileged groups, is the assumption that those who do not align with the norm, those who are outliers or are marginalized, are lesser and deficit. Within education research and policy, it is common for policymakers and researchers to frame educational inequities as deficits linked to race and/or gender (Ladson-Billings, 2006). The perspective of racism and sexism must be explicitly addressed to avoid a dominant perspective and viewing differences as deficits in minoritized individuals or groups. I join others in pushing back on this narrative by referring to inequities as an educational debt (Ladson-Billings, 2006). Instead of inequities indicating any deficiencies in individuals or groups, inequities in education highlight racialized and gendered discrimination associated with majority beliefs.

Personal Reflexivity - How can I ensure my representation resonates with Women of Color and not my own majority beliefs?

Ensuring my representation resonates with beliefs other than my own is something I have wrestled with since I became interested in scholarship involving

minoritized students in STEM disciplines. As a White woman, I shied away from CRT because I felt it was not my space and I was unsure of my place in the discourse surrounding Black and other minoritized students. Rather than risk taking missteps that would cause harm, I kept to the sidelines and attempted to listen and learn. When I began my doctorate program, my own ways of knowing and my past experiences as a biologist were such an embedded part of my identity and self that I did not recognize I relied on "White ways" of knowing. During my master's program in biology, I was not introduced to research methods other than quantitative methods and statistics. I internalized the belief that statistics provided objective, unbiased information about the world. I was unaware of the history of statistics in eugenics and maintaining oppressive structures. Being introduced to social science research and other ways of knowing have expanded my worldview but I am still cautious and tread lightly when entering spaces in which I am the "other." While my intention is to improve social justice with the end goal of improving educational outcomes for Women of Color, I understand that I am also outside of that space as a White woman. I also recognize that the scholarship I produce, especially statistical results, can be used in unintended, harmful ways by others and that the tenets of CRQI can inform my own work and interpretations of others' research. I need to set aside my own feelings of discomfort that come from learning about my own shortcomings and focus on how I can use my education to help elevate others. To ensure that my representation goes beyond my own biases and majority beliefs, I will focus on utilizing methodologies that provide transparency and open the door for critiques. I will

use the tenets of CRT to increase awareness of racism without pretending that I can speak for Women of Color.

Methodological Reflexivity - How is my research agenda influenced by the voices of Women of Color? How can I ensure my representation resonates with Women of Color and not my own majority beliefs?

I believe that the best way for me to ensure that my representation resonates with women of color is to incorporate the scholarship produced by Women of Color and to receive critical feedback of my scholarship from women of color. Representation must be considered at each step of the research process from research design to data collection and analysis with the understanding that the more we steps we use in analyzing data with statistics, the more choices we have to make about what does and does not matter and the higher the chances of human bias being introduced (Gillborn, 2010). Because I do not believe research on Women of Color should be restricted to scholars who are Women of Color, I do not believe the burden of all research decisions should lie with Women of Color. Rather, I believe transparency surrounding research decisions should allow Women of Color to determine whether peer-reviewed research resonates with them and allow open criticism of work that does not. Open critiques and dialogue should be encouraged as a way to move us towards more accurate representations of reality.

Within my own research, I can use reflexivity to explicate my motives and potential biases and find ways to incorporate the voices of Women of Color. By questioning and then exploring the decisions made throughout the research process, I can aim to go beyond my own worldview. Furthermore, inclusion of counter stories and

testimonios (Covarrubias et al., 2018) written or spoken by Women of Color, as part of mixed methods studies, provides voices of Women of Color that are not reflected in statistical data. These qualitative elements are useful in capturing the nuances lost in statistical analyses.

Tenet 5: Voices must represent minoritized individuals.

Tied in with the tenet of data not speaking for themselves is a tenet positing that the voices should represent minoritized individuals, not the majority voices in society. Counter-narratives can be included to pull in voices that contradict dominant narratives. A *testimonios* approach (Covarrubias et al., 2018) is one example of contextualizing and grounding quantitative data. Use of a critical race mixed methodology (CRMM) is another example of integrating the voices of minoritized individuals into quantitative research (DeCuir-Gunby, 2020). Within quantitative research, the idea of not representing the majority opposes a main assumption of quantitative data, the assumption of normality. When data are not normally distributed, common practice is to eliminate outliers as a way to force data into a normal bell curve. While this practice produces better fitting data, it also removes the voices of some individuals and produces data that do not represent minoritized individuals.

Methodological Reflexivity - Are survey items worded from a deficit or asset-based perspective? Are survey items culturally responsive to the population being studied? How am I using language throughout my study?

I believe the HSLS:09 survey items chosen for inclusion in my structural equation model are neutral or, in some cases, asset based. The survey items targeting whether

students see themselves as math or science people reflect a growth mindset. When survey items are developed, there should be adequate input to ensure items are not interpreted as coming from a deficit-based perspective. Additionally, survey items should reflect an understanding of the cultural differences between individuals in the population being studied and should include revisions made based on feedback from People of Color.

Throughout my study, I have reflected on my use of language to highlight the critical lens I am using. At the outset, I found some of my language and research decisions were inconsistent with a critical framework. As a result, I made revisions, such as removing any comparisons between women of color and others to center the experience of women of color and avoid the potential of any deficit framing possible when comparisons are made. I focused on highlighting oppression and its role as the central factor in marginalizing women of color.

Conceptual Reflexivity - ***Are my results presented from an anti-oppressive perspective? Can we use quantitative methods to push back against oppression?***

Personally, I find it difficult to fully address an anti-oppressive perspective in a quantitative study that, in my opinion, fails to capture the nuances of oppressive forces. I continue to struggle with how to expose and address oppression with a structural equation model. The conceptual arguments for using QuantCrit methods are compelling, but I do not believe that all quantitative methods are suitable for adaptation for use in CRT scholarship. For quantitative methods that are conceptually appropriate, we need to further explicate the use of these tools.

At this stage, I offer more detailed descriptions of each stage of research completed during the SEM study utilizing the HSLS:09 data set. The goal of this section is to elaborate on the sequential steps pursued in mapping critical quantitative tenets onto the statistical modeling process.

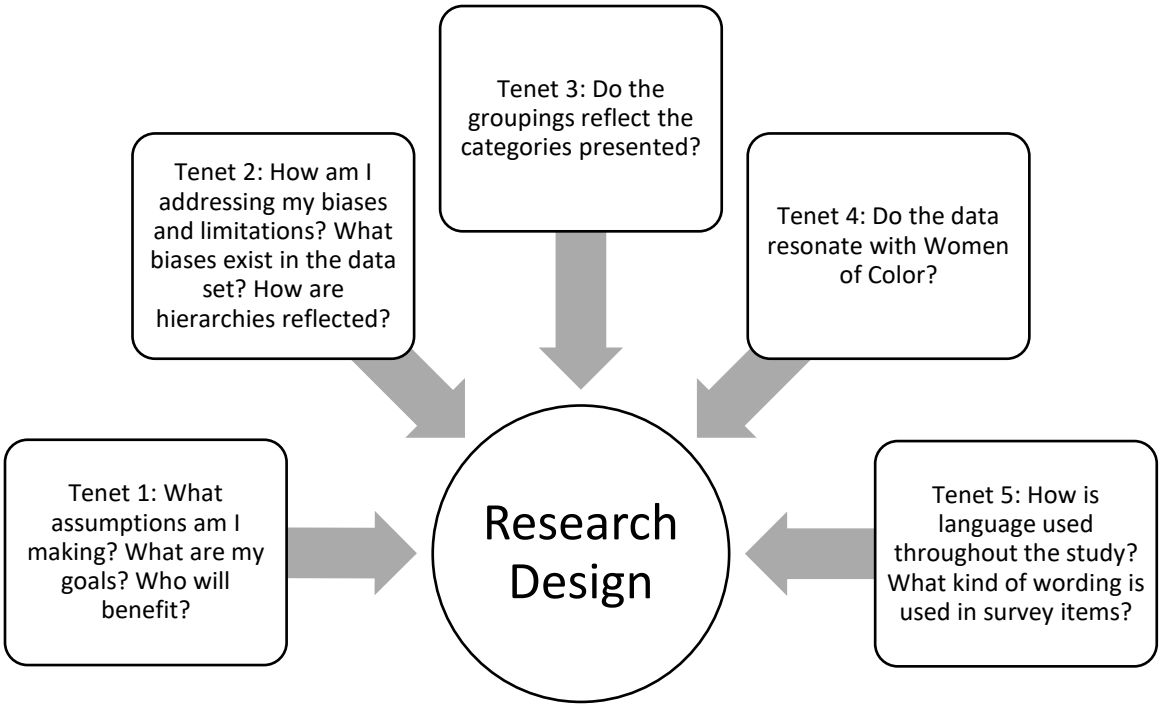
Part 1: Research Design

At the onset of my dissertation research, my goal was to use a quantitative approach to examine the personal characteristics of Black college women who chose a math intensive MECS pathway and intended to graduate with a degree in a MECS field. As my framework solidified, I realized my research was being driven by a CRQI lens and a nonexperimental structural equation model (SEM) approach was chosen as a commonly used statistical approach to allow me to work through examining the process of a QuantCrit approach. The decision to utilize a published dataset and complete the steps to test a model, rather than address the question from a purely theoretical perspective, was an intentional way to discover opportunities and limitations that I may not have become aware of without using a hands-on approach.

Throughout each phase of research, beginning with the overall research design, I used reflexivity prompts linked to each of the five QuantCrit tenets (Figures 1-5). These prompts represent a combination of personal, methodological, and conceptual reflexivity centered around the tenets and enabled me to determine the fit between the research methods and a critical framework.

Figure 1

Reflexivity Prompts Used During the Research Design Phase



An SEM approach is commonly used when research questions involve complex, multi-faceted constructs and go beyond direct effects to include indirect, mediated effects (Keith, 2019). This quantitative approach examines the direct and indirect relationships between relevant constructs, also referred to as latent variables. The model in this study included three latent variables - sense of belonging, STEM identity, and STEM self-efficacy - and one measured variable - intent of college students to enter STEM careers, based on their intended college degree path. These latent and measured variables, chosen based on the STEM higher education literature, are further defined in the sampling technique section. Care should be taken when creating constructs based on previous

literature because of the risk of introducing biases reflected in scholarship created when alternative frameworks have been used.

The overall design was intended to simulate the process of using two stages to test a model of STEM disposition and persistence for Black women, but the small sample size forced my decision to aggregate women students of color – Black and Latina women. The first stage in the overall design was the use of confirmatory factor analysis (CFA) to validate the constructs, also referred to as latent variables, within the model. In the second stage, latent variable SEM was used to explore the fit of my proposed model (Keith, 2019). Throughout the analysis, I attempted to ground my study within a CRQI framework. As discussed in the delimitations within the Introduction, I intentionally chose to avoid a multigroup analysis and comparison of Black and Latina women to other groups because of the critical lens I used in this study and my desire to avoid situating Black and Latina women as deficit in any way. In general, this design was chosen because it mirrors published quantitative STEM higher education studies (Cribbs et al., 2021; Merolla et al., 2012) and involves complex, multi-faceted constructs that have been suggested to have both direct and indirect, mediated effects on STEM students' choices (Keith, 2019). Finally, from a practical standpoint, this study utilized a large federal dataset that is publicly available and similar in nature to data sets often used for educational policy work and decision making.

While statistical analyses are usually a way of examining correlations without inferring causation, one cited strength of SEM is that it allows an inference of causality. While an inference of causality may be seen as a strength in SEM, an inherent danger in

inferring causality within models is the tendency to attribute the socially constructed categories of race and gender as causal in the creation of educational inequities, rather than focusing on racism and sexism as the causes of an "educational debt" (Ladson-Billings, 2006). An inference of causality in SEM models is stated to be possible because knowledge of relevant research and logic, not correlations, are used to draw the paths within a model that indicates cause and effect (Keith, 2019). The acknowledgement that human knowledge and biases are behind data collection and analysis, including statistical models, is implicitly stated within the tenets of a CRQI framework. The ability to make causal inferences from a statistical model can lead to oppressive biases being presented as objective data.

Another cited strength is that the visualized model diagrams used in SEM help readers understand the system being examined. Keith (2019) notes that figural displays "often [make] errors and assumptions more obvious and therefore more likely to be corrected" (p. 294). Within a CRQI framework, these figures are useful in making it easier for individuals who may not be comfortable with numbers to visualize the proposed relationships. An issue with this type of figural display and ease of accessibility is that researcher biases may inadvertently show up in data that are viewed by policy makers as objective.

As described by the tenets of CRQI, a traditional SEM design is inherently racist because, at its core, traditional survey responses and statistical models rely on demographic variables and socially constructed groupings. Race is operationalized in a reductionist essentialist manner when race is presented as a background variable within a

statistical model and racial essentialism obfuscates oppression and social hierarchies (Abrica, 2022). I reflexively considered how to avoid an essentialist approach and operationalizing race as a singular, static identity within this type of study, but I failed to reconcile casting race as a complex social construct when presented with survey data that forces individuals to make dichotomous decisions about their identities. Additionally, by aggregating Black and Latina women into a singular group of underrepresented women of color, assumptions are made about shared experiences based on gender and racial identities as well as individuals' understandings of racism. My conclusion is that by itself, an SEM approach fails to capture the nuances within the lived experiences of Black women pursuing STEM degrees. Below, I explore in detail each step of my research and my reflexive considerations of whether my approach fits with a CRQI approach and, if not, how the step(s) could be revised to uphold the CRQI tenets.

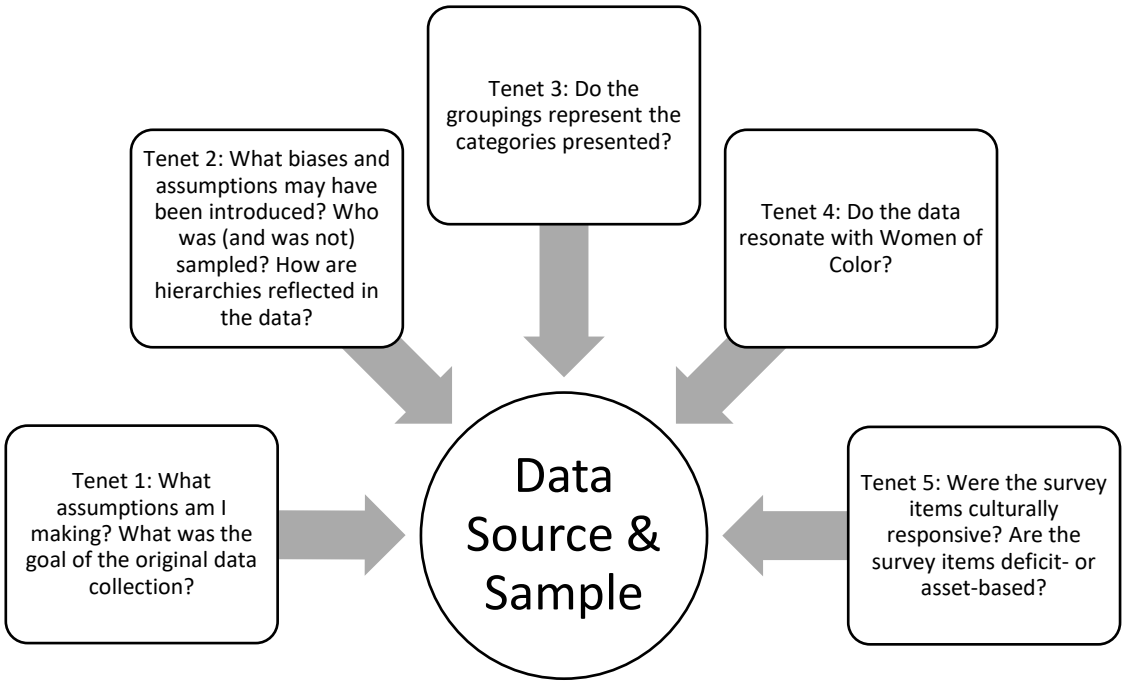
Part 2: Data Source and Sample

As part of a QuantCrit analysis, the purpose and method of data collection for the HSLS:09 data set was explored (Covarrubias et al., 2019) in addition to an interpretation of the model generated for Black and Latina women. Data in the quantitative part of this study came from the publicly available High School Longitudinal Study of 2009 (HSLS:09) data set. The HSLS:09 dataset is a nationwide, longitudinal dataset representing over 23,000 U.S. students from 10 states and 944 schools who began high school in 2009. Initial surveys were gathered from students, parents, high school counselors, and math and science teachers in 2009 with follow-up surveys in 2012 and 2016. Transcripts were also collected in the academic years 2013-2014 and 2017-2018.

From this larger dataset, I used student survey data from students who indicated an intent to major in any of the following STEM fields: computer and information science, engineering, engineering technologies or technicians, biological or biomedical sciences, mathematics and statistics, physical science, science technologies or technicians, health professions and related clinical sciences and who were enrolled in college by February 2016. Students also needed to be Black or Latina women and enrolled in math, natural science, or engineering courses to enable the use of variables targeting students in those courses about whether they felt instructors treated students differently based on their gender and/or race. To explore the fit of the data source and sample with a critical framework, I used the reflexivity prompts shown in Figure 2.

Figure 2

Reflexivity Prompts Used During Data Sampling



The HSLS:09 dataset was chosen because it includes STEM-relevant survey items targeting student sense of belonging, identity, and self-efficacy in addition to providing a view of students' exposure to STEM material and intent to enter a STEM field. Measured variables used to create the constructs or latent variables are based on the relevance of measured variables as gleaned from extant literature on STEM disposition. In conducting a secondary analysis of a dataset, a common practice in educational research, I was required to accept the theoretical framework established by the principal investigators who made methodological decisions throughout a study design. These decisions impact who is sampled and who is not. When I examined the extensive documentation that accompanies this dataset, I was unable to ascertain the biases brought by the principal investigators and any ways in which these biases were addressed. My assumption is that the survey was designed by individuals holding a positivistic or post-positivistic worldview in which survey items provide an objective way to uncover existing truths.

Data from the student data set within the HSLS:09 data set was cleaned and recoded in SPSS prior to being analyzed in MPlus 8.0. The direction of wording for all variables used within the HSLS:09 dataset is positive. Therefore, reverse coding was unnecessary. The items I included use symmetrical Likert scales with item wordings in Table 2. The survey item student responses used to build the constructs of sense of belonging, STEM identity, and STEM self-efficacy all used a symmetrical, four-point Likert scale from 1 ("strongly agree") to 4 ("strongly disagree").

While the HSLS:09 dataset is a nationally representative sample, the collection of quantitative data is inherently biased in terms of who responds. Bias in non-response data

has been documented with women responding more frequently than men and White students responding more frequently than Students of Color (Arellano, 2022). This response bias decreases the input from Students of Color and overemphasizes responses from racial majority individuals. The weighting of scores from Students of Color further magnifies the significance placed on the voices of those who did respond as if they speak for all individuals within the same socially constructed racial group. Furthermore, the survey questions in the HSLS:09 data severely restricted the ability of students to fully indicate their own racial and gender categories. Students could indicate if they identified as "Black," "Hispanic, no race," "Hispanic, race," or "more than one race, non-Hispanic." Gender options were strictly binary. I reflexively considered how to better represent Black women in this type of dataset, but my conclusion is that this type of survey data collection, as guided by CRQI, is inherently problematic in terms of capturing intersecting identities. Survey questions targeting race, ethnicity, and gender or biological sex are useful in terms of capturing crude measures of identities, but they lack the ability to provide nuanced information.

Part 3: Instrument

The original HSLS:09 survey was designed to collect longitudinal data to allow assessment of the impact of educational experiences on students as they transition through high school and into their adult roles in postsecondary education or the workforce. As opposed to other longitudinal datasets, this dataset included survey items designed to track the pathways of students from 9th grade into STEM disciplines in college. The dataset contains measures of student achievement in mathematics and

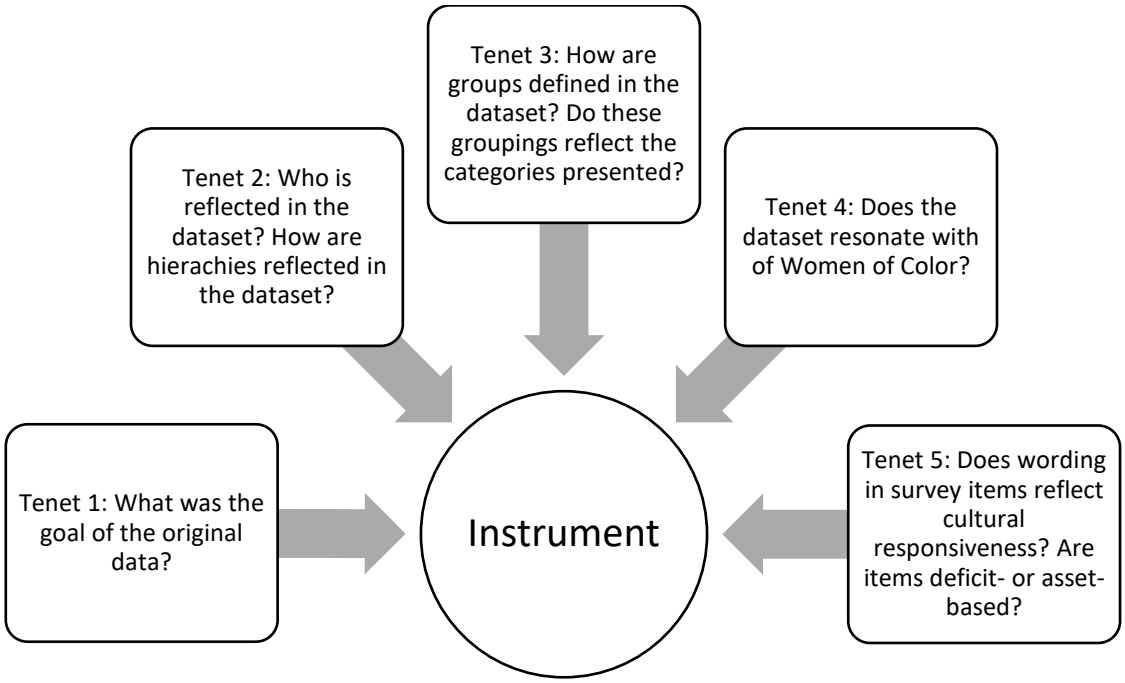
science. One area of policy and research issues addressed in this longitudinal study is math and science education (https://nces.ed.gov/surveys/hsls09/policy.asp). In particular, there is a focus on determining the factors that lead to students enrolling in Algebra I as high school freshmen and how this math trajectory influences entry into STEM versus non-STEM pathways. Oppressive forces at work prior to high school are not captured and students were not surveyed about differences in treatment of students based on differences in race or gender by instructors of math and science classes until they were enrolled in college math and science classes.

Data collection began in 2009 when a cohort of students were entering high school and continued with sampling at different intervals. In addition to demographic characteristics, information was gathered about activities and topics such as decision-making regarding postsecondary education and potential majors with an emphasis on STEM careers. While not used in this study, there are also transcripts and financial aid records available in the restricted use data set. Survey questions targeted experiences from the perspectives of students, parents, principals, science and mathematics teachers, and high school counselors. Different modalities – online, phone conversations, in-person surveys – were used to collect data. Documentation with the data set indicates that paper and online surveys were completed in school settings, but there could still be potential access issues. Of the extensive variables provided, I chose variables that, based on my perspective and knowledge from conducting a literature review, align with student characteristics identified as part of one's STEM disposition (STEM identity and STEM self-efficacy) or that provide insight into how racial and gendered biases within STEM-

specific courses impact sense of belonging – variables regarding whether students felt instructors in their math, natural science, computer science, and/or engineering courses treated students equally independent of race or gender. Reflexivity prompts surrounding the tenets of QuantCrit were used to examine the instrument (Figure 3).

Figure 3

Reflexivity Prompts Used to Examine the Instrument.



Constructs

The constructs, or latent variables, used in the model reflect variables that have been linked to STEM disposition and are also influenced by racism and sexism (Carlone & Johnson, 2007; White et al., 2019). For each construct – sense of belonging, STEM

identity, and STEM self-efficacy – the variable names, survey questions, and Likert scales used are presented in Table 4. Some of the HSLS:09 survey items are linked to constructs based on similar questions and statements summarized by Trujillo and Tanner (2014). It is important to be aware that attempting to disentangle factors that are influenced by racism, such as ranking by prior attainment or parental education and involvement, leads to distortion of reality and reinforces racial inequities. Because of this, I avoided inclusion of constructs such as SES and parental involvement, constructs that are often included in SEM models utilizing the HSLS:09 data set (Kurban & Cabrera, 2020a).

I chose constructs of interest (Table 4) based on previous STEM literature delineating STEM disposition – sense of belonging, self-efficacy, and identity (Carpi et al., 2017; Shin et al., 2016). The constructs are as follows: (a) **sense of belonging** – formed from six variables indicating student perception of treatment by MECS instructors based on the student's gender or race; (b) **STEM self-efficacy** – four variables indicating student perception of their ability to succeed, and whether they believe anyone can develop math skills; (c) **STEM identity** – formed from six variables indicating a student's perception of whether others see them as math/computer/electrical or mechanical people, and how they see themselves situated in those fields; and (d) **intent to enter a STEM career** – based on a student's chosen field of study within a STEM discipline. The first two constructs – sense of belonging and STEM self-efficacy – serve as mediating variables. The third construct - STEM identity - is a latent independent

variable. The dependent variable is a student's intent to complete a STEM degree, based on their declared college major in a STEM discipline.

Table 4

Constructs and Variables from HSLS:09 Dataset

Construct	Variable	Survey Question	Scale Used
Sense of belonging	MTHMF	How much do you agree or disagree that your math instructor(s) treated male and female students differently?	1=Strongly agree 2=Agree 3=Disagree 4=Strongly disagree 9=Not applicable or Don't know
	SCIMF	How much do you agree or disagree that your natural science instructor(s) treated male and female students differently?	
	CSIMF	How much do you agree or disagree that your computer science or technology instructor(s) treated male and female students differently?	
	ENGMF	How much do you agree or disagree that your engineering instructor(s) treated male and female students differently?	
	MTHRC	How much do you agree or disagree that your instructor(s) in math course(s) treated students of different races differently?	
	SCIRC	How much do you agree or disagree that your instructor(s) in natural science course(s) treated students of different races differently?	
	CSIRC	How much do you agree or disagree that your instructor(s) in computer science or technology course(s) treated students of different races differently?	
	ENGRC	How much do you agree or disagree that your instructor(s) in engineering course(s) treated students of different races differently?	

Table 4 continues

Construct	Variable	Survey Question	Scale Used
STEM identity	MPERS1	How much do you agree or disagree with the following statement? You see yourself as a math person.	1=Strongly agree 2=Agree 3=Disagree 4=Strongly disagree
STEM identity	SPERS1	How much do you agree or disagree with the following statement? You see yourself as a science person.	
	MPERS2	How much do you agree or disagree with the following statement? Others see you as a math person.	
	SPERS2	How much do you agree or disagree with the following statement? Others see you as a science person.	
Self-efficacy	TPERS1	How much do you agree or disagree with the following statement? You see yourself as someone who is good at solving problems using computers.	1=Strongly agree 2=Agree 3=Disagree 4=Strongly disagree
	TPERS2	How much do you agree or disagree with the following statement? Others see you as someone who is good at solving problems using computers.	
	EPERS1	How much do you agree or disagree with the following statement? You see yourself as someone who is good at figuring out how mechanical and electrical things work.	
	EPERS2	How much do you agree or disagree with the following statement? Others see you as someone who is good at figuring out how mechanical and electrical things work.	
	MLEARN	How much do you agree or disagree with the following statement? Anyone can learn to be good at math.	
	SLEARN	How much do you agree or disagree with the following statement? Anyone can learn to be good at science.	
Intent to enter STEM career	FIELD2	11-computer and information sciences; 14-engineering; 15-engineering technologies & technicians; 26-biological & biomedical sciences; 27-mathematics & statistics; 40-physical science; 41-science technologies & technicians; 51-health professions & related clinical science	

When reviewing these constructs, I became aware of the limited scholarship on Black students in higher education STEM literature surrounding STEM identity and self-efficacy outside of a few Black students attending Primarily White Institutions (PWIs). Quinlan et al. (2022) addressed this limitation with their development of a science self-efficacy instrument created with "considerations of the cultural, social, and historical impact of being Black in STEM" (p. 1598). The use of constructs and questions developed primarily with White male students in mind is both racist and sexist and requires attention prior to the development of survey questions to gauge how well we can capture the experience of Black and other racially minoritized students. Within the public use data set, the variable for indicating sex ("X1SEX") allows for choice of "male" (n=11,973) or "female" (11,524) with 6 missing responses. Gender identity can be accessed within the HSLS:09 data set if the restricted use data is used. In future studies, I would use gender identity to allow inclusion of individuals who identify as a woman rather than relying on biological sex.

As described by the tenets of CRQI, the measured variables and the constructs formed from the measured variables are inherently racist because they reflect socially constructed categories. The "X1RACE" variable allows the singular choices of race/ethnicity with only one option for "more than one race, non-Hispanic." I reflexively considered how to make survey items that are not racist or sexist, but my conclusion is that survey items that restrict the ability to capture nuanced characteristics are inherently flawed. As guided by a CRQI framework, my reflection of this process is that survey items that restrict individuals' choices of identifiers creates inherently racist variables.

Additionally, making generalizations is grounded in a positivist paradigm and viewing numbers as neutral and objective is grounded in White logic (Garcia & Mayorga, 2018).

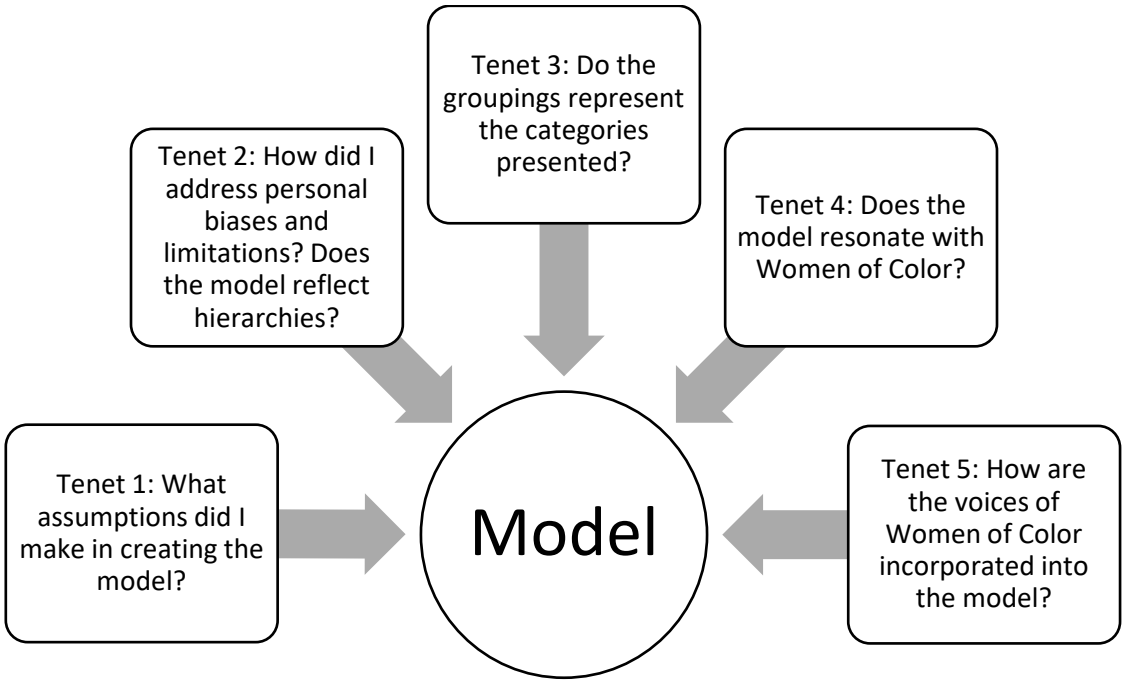
Part 4: Model

The construction of a model relies on researchers' interpretations of relevant literature and previous research. Therefore, a researcher's biases and paradigm influence the model and causal statements made about the model. Logic and theory should be fully explicated through reflexivity and consumers of this research should have an in-depth understanding of how models are developed. There must be transparency that enables others to follow the decision-making processes that can lead to the introduction of oppressive interpretations. Reflexivity prompts were used to examine my proposed model (Figure 4). The multiple decision points involved in complex statistical modeling, in combination with the ease of visualizing what is presented as causal pathways, makes structural equation modeling particularly vulnerable to misrepresentation and misuse when viewed as objective evidence by education policymakers.

To build my proposed model (Figure 5), a literature review was conducted to determine the constructs and relationships between constructs which are presented in an initial proposed structural equation model. As mentioned in my description of the constructs above, I realized retrospectively that the constructs in extant literature were developed primarily with White male students in mind and may not be the best instrument for capturing the experiences of Black and other racially minoritized students. Within my model (Figure 5), the constructs (also referred to as latent variables) are

Figure 4

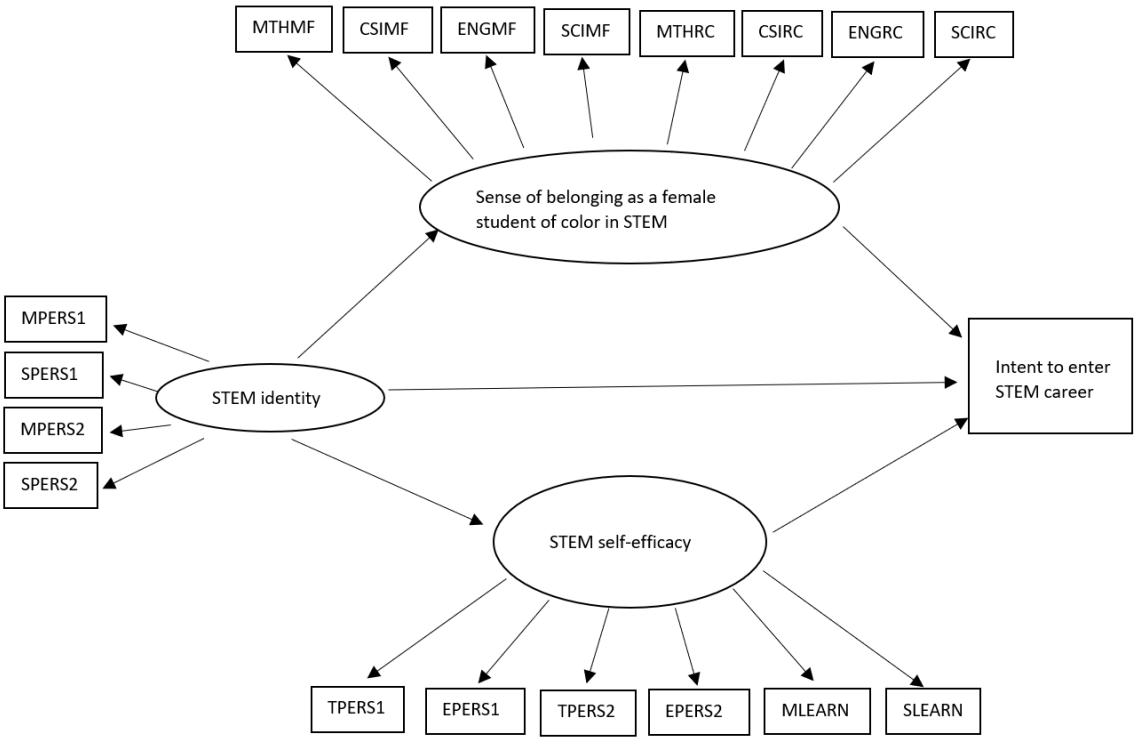
Reflexivity Prompts to Examine the Proposed Structural Equation Model.



shown in ovals. The constructs included in my model are sense of belonging in STEM, STEM self-efficacy, and STEM identity. I proposed that STEM identity had both direct and indirect effects on intent to major in a STEM discipline. The proposed relationships for STEM identity included mediation through both sense of belonging and STEM self-efficacy. I also proposed that STEM self-efficacy and sense of belonging directly influence intent to major in a STEM discipline. The measured variables from survey data within the HSLS:09 data set, are indicated by rectangles and are further defined in Table 4 which includes the variable names, survey questions, and scales used for each survey question.

Figure 5

Initial Model Proposed for Structural Equation Modeling, Based on Factors from Literature.



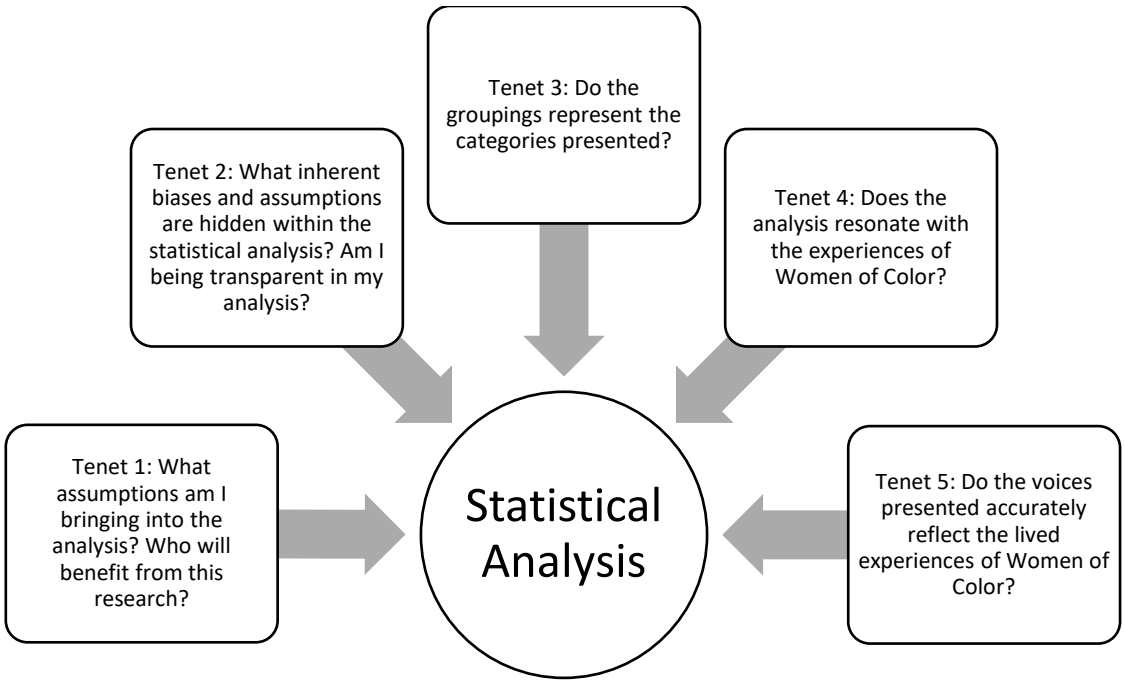
Part 5: Statistical Analysis Procedures

This section provides details of how statistics would be used to analyze the model shown in Figure 5. Initial data analysis consists of confirmatory factor analysis (CFA) to determine how well the proposed constructs in Figure 6 are supported by the measured variables or factors in the HSLS:09 dataset. Next, latent variable structural equation modeling (SEM) in MPlus version 8.7 was used to analyze the proposed model. While this was a methodological study using reflexivity and the results of the model were not my focus, I did use MPlus version 8.7 for my reflexive analysis and have therefore

included figures for the CFA and SEM diagrams in Appendices A and B, respectively. Again, the CFA and SEM steps were completed as a way to allow me to determine the viability of this type of study through reflexivity on the process as a methodological approach to the research problem. Reflexivity was used to explore the fit between a structural equation model analysis and a critical framework (Figure 6).

Figure 6

Reflexivity Prompts to Examine the Analysis of a Structural Equation Model



Analysis of the Model

The first stage of analysis involved the use of confirmatory factor analysis (CFA) to ensure the proposed indicators, the measured variables within the HSLS:09 dataset,

load significantly onto the constructs (Keith, 2019) in the SEM model for Black and Latina women (X1SEX = 2 for female and X1RACE = 3 for Black; 4 for Hispanic, no race indicated; and 5 for Hispanic, race indicated). The constructs presented in the proposed model were formed from more than three indicators, allowing a CFA to be run with each construct individually. The first factor loading for each construct was set to 1.0; other loadings, variances, and covariances were freely estimated. Factor loadings above 0.4 were considered as evidence supporting a strong association between the measured variables and the construct (Keith, 2019). The variables MLEARN and SLEARN were removed from the subsequent model as they were not found to be associated with the STEM self-efficacy construct. The survey questions used to form MLEARN and SLEARN asked students whether they felt anyone could learn math or science, respectively.

After validating the four constructs within this model using CFA, latent variable SEM was used in the second stage to examine direct and indirect effects between the latent variables (constructs) in the model. Multiple model fit indices would be used to determine the strength of the fit between the proposed structural model and the data. In an empirical study, alternative model fit indices would be examined to determine the best fit and model parsimony. Model fit indices used would be comparative fit index (CFI), Tucker-Lewis index (TLI), root mean square error approximation (RMSEA), standardized root mean residual (SRMR), Akaide information criterion (AIC), and Bayesian information criterion (BIC). CFI and TLI are considered significant if equal to or greater than 0.90 (Keith, 2019). RMSEA and SRMR are considered significant if equal

to or less than 0.80 (Keith, 2019). AIC and BIC would be used when comparing competing models. For both AIC and BIC, a smaller number indicates a better fit and more model parsimony (Keith, 2019). Chi-square statistic would also be used but when working with small sample sizes, such as those found in studies of minoritized individuals in STEM, and the reliance of chi-square on sample size, this statistic would only be used as one part of a comparison of competing models.

Validity

The classifications provided in the HSLS:09 data set make it difficult to categorize majors into STEM and non-STEM majors. Also, as noted by NCES, the complex design and weighting in this dataset impact standard errors and may require manual adjustments with an R plug-in program when using SPSS and other statistical software packages (https://nces.ed.gov/surveys/hsls09/hsls09_data.asp) to avoid underestimating standard error. An underestimation of standard error can cause Type 1 error in which statistical significance is falsely identified. Threats to internal validity include missing values and a small sample size of Black women. In an attempt to overcome the issue of a small sample size, I aggregated data for Black and Latina women to allow use of a structural equation model. However, from a critical race standpoint, a small sample size should not prevent disaggregating data because aggregation leads to erasing critical respondents from analysis and treating minoritized individuals as a homogenous group with similar experiences. From this standpoint, I should have looked into alternative quantitative methods that would allow me to better represent Black women in STEM rather than aggregating to allow use of structural equation modeling.

Construct validity, how well the items measure concepts, should also be considered (Creswell & Creswell, 2018). In this study, the constructs of sense of belonging, STEM self-efficacy, and STEM identity are formed from measured variables, based on previous literature, and validated using CFA. To address validity concerns, I incorporated the use of peer debriefing, primarily in meetings with my advisor, Dr. Abrica, in which I was asked questions that help form a more resonant, coherent study. This is one area in which a model fails to represent reality because regression analyses, the basis of structural equation models, rely on the inclusion of relevant variables and well-established theory. CRT describes the centrality of oppression which is simply not represented with the data set I chose. The HSLS:09 data set variables I used capture a snapshot of how students perceive their treatment by college instructors in math and science courses but fails to capture the historic and structural oppression faced by Black and Latina women persisting in STEM disciplines. In retrospect, I realize the measured variables I chose (Table 4) to build constructs for sense of belonging, STEM identity, and STEM self-efficacy are all influenced by oppressive forces, but I did not account for this in any meaningful way and was unable to reflexively identify a way to do this in a strictly quantitative study.

Reliability

By describing my techniques for using reflexivity at each stage, providing details about the steps of the quantitative procedures in detail, and using a public dataset, I addressed reliability and the ability of others to replicate my study. There is high reliability in the use of the HSLS:09 dataset because this dataset is static and publicly

available. There were limitations introduced as data was missing for students who did not enroll in any or all of the course options – math, natural science, computer science, engineering - in which students were asked whether they felt students were treated differently based on race and/or gender. Additionally, Black and Latina women who changed from STEM to non-STEM majors were not captured in this study and their responses to questions about perceived racism and/or sexism was not captured.

Part 6: Results

One commonly cited challenge in research with marginalized groups in STEM is a low sample size number (Nissen et al., 2021) which leads to the issue of aggregating different STEM subfields and different marginalized groups to increase sample size even though we know that doing so erases heterogeneity. The choice of a large-scale data set should allow more disaggregation of marginalized groups, but I was still unable to incorporate enough individuals to create a structural equation model with only Black women in math-intensive fields or even Black women in all STEM subfields. To attempt to overcome the limited sample size, I aggregated Black and Latina women in all STEM disciplines to allow development of a viable model. Regardless of intent, statistical analyses that aggregate minoritized individuals as if they are a homogenous group with similar experiences contributes to the problem of erasing heterogeneity, but quantitative methods and statistics require larger sample sizes than the number of Black women in MECS disciplines provides. Overall, the reliance on large sample sizes to get statistically significant *p*-values is problematic in research on any minoritized groups in STEM because sample sizes are too small for significant *p*-values without aggregating data. As

an alternative to using *p*-values, confidence intervals or standard error can be used, but this requires a shift away from traditional statistical methods (Van Dusen & Nissen, 2020). While standard errors provide a way to present results when working with smaller sample sizes, this method is more tedious for consumers of research who must re-evaluate how we determine significance of results.

As a reminder, this study was a reflexive analysis of my experience as an emerging scholar performing a QuantCrit study and the focus was on the methodology, not on the structural equation model presented. The CFA and SEM results were included (Appendices A, B, and C) to illustrate how this type of study would be completed. Although the empirical results of the SEM data are not my focus, I feel I would be remiss in not mentioning the CFI and TLI were not significant with the structural equation model that I proposed (Appendix A). RMSEA and SRMR were also not significant. The confirmatory factor analysis (Appendix B) indicated a lack of fit for two of the proposed variables – MLEARN and SLEARN. Therefore, these variables were removed prior to running the proposed structural equation model (Appendix C). Keeping in mind that the model fit indices did not indicate that the model was a good fit, the SEM diagram produced from the MPlus output (Appendix C) makes it appear that sense of belonging, based on whether Black and Latina women felt that college instructors of STEM courses treated individuals of different races and genders differently, is not a mediating variable in students' intent to enter a STEM career and does not directly influence intent. Additionally, intent is also not directly predicted by a student's identity.

Chapter 5

Discussion

This dissertation unconventionally offered a reflexive account of conducting a quantitative study using critical quantitative approaches. In reviewing literature on both content: Black women in STEM, and methodology: how to do critical quantitative methods, I learned that there are very few examples of how to carry out the recommendations of QuantCrit methodologists in applied studies. This lack of knowledge/understanding impedes doctoral students who, like me, are exposed in their graduate curriculum to critical race and other critical approaches while simultaneously learning tools of research in a more traditional, quantitative sense. While the QuantCrit literature provides adequate discussion of the rationale behind QuantCrit research (Covarrubias & Vélez, 2013; Gillborn et al., 2018), there are limited examples exploring how reflexivity can be used to investigate the steps of a QuantCrit study. For example, some QuantCrit empirical studies incorporate positionality statements, indicating use of reflexivity, but lack explicit evidence of reflexivity throughout the study (Lopez & Jean-Marie, 2021; Nissen et al., 2021; Van Dusen et al., 2022). The use of reflexive questions in QuantCrit studies is best addressed in recent methodological work by Castillo and Gillborn (2022) and Pearson et al. (2022b). My own reflexive account provided a framework for what the use of reflexive questions looks like in practice in a QuantCrit study and allowed me to explore the viability of QuantCrit methods. This dissertation offers a methodological contribution to assist in the advancement of racial equity through the application of CRQI tenets in quantitative research.

Through my reflexive exploration of a QuantCrit structural equation model study, I realized that the reliance on traditional survey results and statistical models in much of the STEM higher education literature is inherently racist. Privileged groups, primarily White males, are normalized and race is typically reduced in an essentialist manner in which race is treated as a background variable that obfuscates oppression and social hierarchies (Abrica, 2022). The constructs of sense of belonging, self-efficacy, and identity within my structural equation model are based on higher education literature that is not studied from a CRT perspective. We know that racial oppression and White supremacy limit the access of racially minoritized Black and Latina/o/x students to resources, including STEM higher education (McGee, 2016). Quantitative research on racially minoritized students in STEM tends to utilize frameworks such as social cognitive career theory (SCCT) or other frameworks addressing individuals, rather than the larger systemic issues of race, racism, and oppression which are addressed with a CRT perspective. With empirical literature that is not informed by a CRT perspective, there is limited engagement with race and racism which needs to be addressed openly. Reflexivity, as a method, affords a means to engage with the tenets of CRT and center race and oppression.

This dissertation is my reflexive account of attempting to conduct a critical quantitative research study of Black women pursuing STEM degrees at two or four-year colleges and universities. I examined how tenets of critical quantitative (QuantCrit) methods in higher education could be applied to traditional quantitative approaches for studying Black women in STEM. Through my exploration, I found that my approach and

the available tools for performing structural equation modeling were not sufficient to allow disaggregation of Black women in STEM higher education even from a large dataset. Attempting to restrict a QuantCrit study to Black women in math-intensive fields such as engineering would be even less feasible. Because my intention was to focus on Black women, my final dissertation title reflects my intent despite the challenges that force aggregation of Black women with other Women of Color. The disconnect between the title of my dissertation and the reality of QuantCrit work reflects one of the challenges I found as I completed this dissertation.

Throughout the dissertation writing process, I grappled with tension conceptually and methodologically. Internally, I had to sit with the tension of being a White woman discussing the salience of race and racism in higher education. I am almost afraid to discuss that internal tension for fear of being seen as attempting to pull attention to my own needs and away from the focus of social justice and racially minoritized individuals. I needed to reconcile how I could approach this topic as an ally without appropriating a framework designed to be utilized by People of Color. I entered a space of tension in methodologies – tension between quantitative and qualitative methods and tension in statistical theory when approached through a critical lens. I encountered internal tension between holding a post-positivistic paradigm while conducting biological research and a social constructivist paradigm in engaging with the realities experienced by minoritized individuals in social science research. The inability to reconcile these tensions produced frustration as I realized there are no simple solutions, but I can continue to be part of the

discourse in using CRT tenets to inform my own work and conversations I engage in with those around me.

As a White woman and developing researcher, I am both receptive to my quantitative training in conducting higher education research as well as the critical perspective that traditional quantitative approaches are problematic for a variety of reasons, a main reason being that quantitative approaches reduce race to a background variable and cannot account for the complexity of racialized experiences among People of Color (Zuberi & Bonilla-Silva, 2008). On the one hand, higher education researchers have conducted countless studies using Black and other Students of Color as a sample. On the other hand, a large body of qualitative studies document the complex, nuanced, and complicated experiences of racially minoritized populations. How can these approaches be reconciled? Should they be reconciled? As a student learning about critical race theory as well as quantitative research approaches, I decided to focus on questions around how to bring both approaches together. By bringing these approaches together, I was able to provide a reflexive account of the thought processes that should go into each step of a study centering minoritized individuals. Reflexivity is one approach to uncovering the inherent biases within previous literature as well as our own research.

Implications and Recommendations for Research and Teaching Quantitative Methods

One of the earliest obstacles I faced in my design of an SEM study was the realization that I would be forced to aggregate data rather than focus on Black women in MECS disciplines – the area of greatest underrepresentation - because of the small

sample size. Aggregating data by lumping together Black and Latina women in all STEM fields leads to homogenization and erasure of the unique, intersectional experiences of Black women in MECS fields. The approach I chose – SEM – appears to be White-centered and approaches the problem from my own majoritarian beliefs which diminish the stories and counter stories of People of Color. The requirement of a large sample size to obtain statistically significant results leads me to feel that this quantitative method is not compatible with exploring a minoritized population.

Upon retrospect, I feel my use of the HSLS:09 dataset within a CRQI framework was inappropriate because the methodology itself was not critical. There is no consideration for the framework utilized in a study when it comes to the mechanics of data input in MPlus. This study allowed me to realize the need for the development of more robust quantitative techniques that are applicable within a CRT/CRQI framework. Furthermore, this study led me to consider whether a "critical" study is critical in interpretation only or if the methods must be critical as well. My conclusion is that all components of a study should be critical which requires the development of exemplars and guidelines that go beyond the conventional methods I was introduced to as a doctoral student. For those teaching statistics and for students learning quantitative methods, methodological reflexivity can be used to examine each step of the process (Table 3), especially when comparisons are made between groups.

Any models proposed and analyzed are based on previous literature and theory as interpreted by the researcher(s) entering them. The model I proposed appeared to represent the constructs that form one's STEM disposition, based on extant literature, but

the research that I drew from across various fields to create my proposed model most likely used methods that reflect oppression. Drawing from previous research based in oppressive techniques, particularly those that emphasize meritocracy or color blindness, makes it unlikely to produce work that does not also reflect oppression. If the variables and models I am using were normed on affluent white males and then fit onto Women of Color, the measure itself is not going to fit because the experiences are not comparable.

Something I did not consider when developing this study was the manner in which oppression is hidden during data collection. Culpepper and Zimmerman (2006) found response bias in survey responses, especially with Likert-type scales, in which Latina/o/x individuals avoid responses in the middle of the range and rely more heavily on responses at extremes of the scale. In a comparison to White individuals who tend to choose mid-scale responses, individuals who choose extremes necessitate quantitative corrections. One can infer that researchers making these corrections to conform to statistically sound methods are positioning individuals answering in ways other than the "White way" as aberrant or deficit and the push to normalize data eliminates the voices of minoritized individuals. This concealed form of oppression is of significance when working with racially minoritized individuals.

Oppression is also tucked away in experiences that have occurred prior to high school. The HSLS:09 dataset begins tracking math and science achievement when students are beginning high school. By that point in time, students experiencing oppression have already been provided fewer educational opportunities. While these forces cannot be teased out of the data, it is critical to recognize their existence as part of

the measured variables. These unseen forces play a role in shrinking the potential sample before the sample is even collected.

At an overarching level, it is difficult to weave together a CRQI framework with traditional quantitative methods. The stories and counter stories presented through qualitative methods emphasize individuals while SEM and traditional quantitative methods, in general, focus on groups. Traditional quantitative methods are also broad in scope and lead to essentialism which obfuscates social hierarchies and oppression (Abrica, 2022). The findings from traditional quantitative studies are generalizable and rely on aggregated data and the results are independent of context. How can we reconcile these methods with a critical approach dealing with marginalized individuals who appear as outliers in statistical data? We should be questioning widely accepted models and assumptions that may not be accurate for all, but when we rely on the same methods used to create those models, we simply reproduce the status quo. Rather, we should be searching for models, measures, and analytic practices that produce revisions that better represent marginalized individuals.

Summary of Key Recommendations

Based on the discussion points raised, the following section outlines specific recommendations for higher education graduate programs teaching quantitative courses as well as ways to amplify the use of reflexivity in higher education scholarship.

Recommendations Addressing QuantCrit Methods

Use reflexivity prompts such as the ones used in this dissertation to explore each stage of the research process. The value of reflexivity is described within literature

but as a new scholar, using reflexivity as a method was only clearly delineated in a few journal articles targeting qualitative methods outside of educational research (Lazard & McAvoy, 2020; Nadin & Cassell, 2006). Future research should consider reflexivity as a methodological approach that can disrupt notions that quantitively approaches are bias-free or without subjectivity involved.

Incorporate critical theory in each stage of the research process and be transparent in the mapping of critical tenets onto any quantitative methods used. By mapping QuantCrit and other critical frameworks into the research process, students of quantitative methods can better learn how to integrate traditional quantitative approaches with critical theories and perspectives.

Continue exploring the viability of QuantCrit and alternatives. One alternative to QuantCrit research, Critical Race Mixed Methods (CRMM) research (DeCuir-Gunby, 2020), helps integrate qualitative and quantitative methods.

Provide guidance for datasets that work within a CRQI framework. Survey data alone in a large national dataset is limiting when working with minoritized populations.

Expand publication access in peer-reviewed journals in which open dialogue in the form of reflexivity and critical quantitative scholarship that does not follow a traditional format is not only allowed but encouraged. My own position of privilege, as a White woman writing a dissertation, allowed me to utilize an unconventional method to answer a research question. Those in a position to allow publication of research that does not fit with the standard White way of knowing should use their power to expand

access for Scholars of Color and others who chose to explore alternative ways of knowing (Wofford & Winkler, 2022).

Recommendations Addressing Institutions of Higher Education

Discuss the history of statistics in quantitative research courses. The racist history of statistics does not preclude the use of statistics as a tool, but the history of statistics needs to be addressed.

Discuss alternative ways of knowing in addition to White ways of knowing. A knowledge of research paradigms and alternative ways of knowing allows us to explore what we view as legitimate and scholarly knowledge. Additionally, this knowledge creates a space for movement beyond customary quantitative research methods that do not fit when accounting for race and racism. Methodologies beyond White ways of knowing exist (https://weallcount.com/) and should be taught in graduate school training programs alongside other research techniques.

Conclusions

As part of my own knowledge seeking during the dissertation process, I found myself exploring QuantCrit methods and the use of CRQI tenets as an alternative to traditional quantitative methods. At this point, the conceptual arguments have been made (Covarrubias & Vélez, 2013; Gillborn et al., 2018) but there is still under development of methodological guidelines. I quickly found that QuantCrit does not have its own tools, but instead utilizes traditional quantitative tools within a critical framework. While there are some recommendations made in the literature (Castillo & Gillborn, 2022) that guided my inclusion of personal, methodological, and conceptual questions, I found that

performing a QuantCrit analysis with a public dataset is challenging primarily because survey questions and statistics, as tools, are simplifying and dichotomizing. The requirement of a large sample size forces aggregation of Black women with other Women of Color which makes it difficult, if not impossible, to account for their unique racialized and gendered experiences. The issue of sample size becomes even more problematic when attempting to work with the very limited sample sizes of Black women in MECS fields. Because of the issue of sample size, I was unable to reconcile how to perform a QuantCrit study on Black women in the math-intensive fields in which they remain underrepresented. Statistical models can measure the impact of the oppressive structures that create marginalization, but QuantCrit research is limited by its failure to capture the nuances of educational debt (Ladson-Billings, 2006; Nissen et al., 2022). My conclusion is that post-positivistic research in social science merely repeats the status quo, but incorporating a critical paradigm requires a re-working of the methods we are utilizing.

If we "continue to study race without critically examining racism" (Harper, 2012, p. 25) we will continue to miss the mark on achieving social justice. We have adequate research on the characteristics of successful STEM students and statistics on minoritized students, but a gap still exists between qualitative and quantitative research anchored in CRT. As Gillborn et al. (2018) posit, the use of QuantCrit is "well placed to chart the wider structures, within which individuals live their everyday experiences, and to highlight the structural barriers and inequalities that differently racialized groups must navigate" (para. 3), but the history of statistics and subjectivity introduced into all

research by human bias require a close examination of quantitative methods from the formation of research questions and data collection through the analysis of data. Within this framework, I explored the process of completing a QuantCrit study on Black women in STEM higher education pathways. Through reflexivity, I investigated the challenges of being a doctoral student attempting to utilize QuantCrit methods. Some of the challenges encountered were personal challenges related to my own intersecting identities and research background. Other challenges were methodological and conceptual in nature. Ultimately, I believe QuantCrit research alone is not enough; triangulation with qualitative studies and methods is required to tease out nuances in the relationships between factors and to bring in the voice of those who are oppressed. Additionally, while CRQI analyses are anchored in social justice goals and policy makers give preference to numerical data, scholars must use caution in providing quantitative data that others may reinterpret "to justify exclusion and create structures of domination and oppression to limit access to education for marginalized groups" (López et al., 2018, p. 201).

As scholars, we must ask ourselves: Do the benefits of utilizing traditional methods recognized by mainstream policy makers outweigh the costs associated with these methods? My conclusion from my reflexive account is that the benefits of blindly fitting traditional research methods onto minoritized populations do not outweigh the risks associated with maintaining the status quo of oppression. Rather, we need to explore alternatives to traditional research methods that allow us to center social justice and move away from racist methods.

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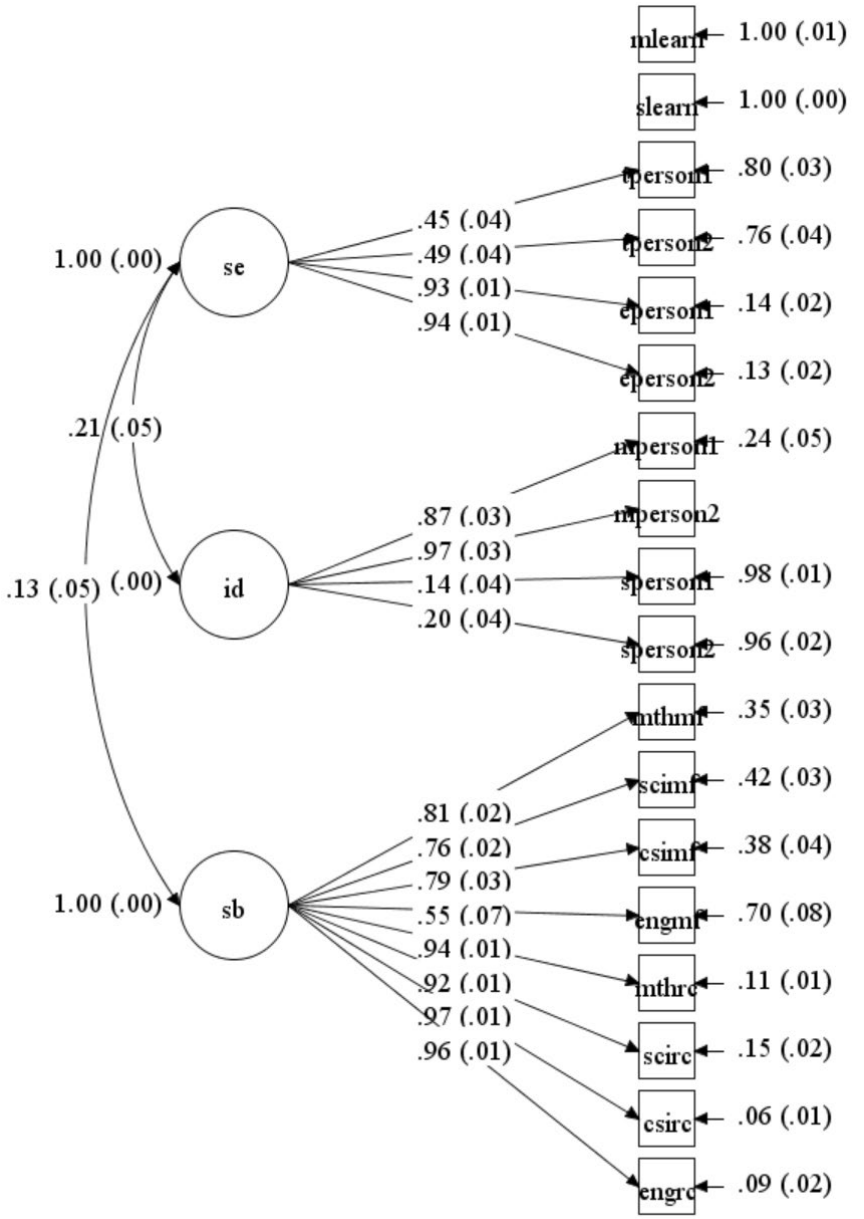
Appendix A

Confirmatory Factor Analysis with Standardized Factor Loadings, Residuals, and Standard Errors

Confirmatory Factor Analysis with Standardized Factor Loadings, Residuals, and Standard Errors



Appendix B

Structural Equation Model with Estimated Factor Loadings, Latent Factor Correlations, and Standard Errors

Structural equation model with estimated factor loadings, latent factor correlations, and standard errors.