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To be or not to be a Math Person: Math Identity Dissonance in Ninth Grade Students

by

Noah Heller

A dissertation submitted to the Graduate Faculty in Urban Education in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York

2015
This manuscript has been read and accepted for the Graduate Faculty in Urban Education in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

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THE CITY UNIVERSITY OF NEW YORK
Abstract

To be or not to be a Math Person: Math Identity Dissonance in Ninth Grade Students

by

Noah Heller

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What student-level variables (e.g., demographic, attitudes toward math, attitudes toward school, and prior math achievement) affect the construction of a dissonant math identity? Research shows that the number of science, technology, engineering, and math (STEM) occupations is growing twice as fast as all other industries. Further, math achievement, more than any other academic factor, determines whether students have access to STEM majors in college and thus pursue STEM careers. Concomitantly, numerous studies have shown that the ways in which students identify with mathematics have a profound impact on their immediate performance and future decisions to pursue math and math-related majors and careers.

Employing the base year of the High School Longitudinal Study of 2009 (HSLS: 09), a nationally representative sample of over 21,000 ninth grade students, this dissertation explores factors that contribute to math identity dissonance (MID). Math identity dissonance is defined as the difference between a student’s personal math identity (i.e., the degree to which she sees herself as a math person) and her social math identity (i.e., the degree to which she believes others see her as a math person). While MID has not been thoroughly explored as a theoretical construct in previous research,
using it in conjunction with similar theories (e.g., academic mindsets, stereotype threat, and communities of practice) will offer a nuanced window into students’ distinct struggles identifying with mathematics. Using multivariate analyses to better understand factors that contribute to MID, this study informs education research and practice aimed at improving inclusive frameworks for all students of mathematics.
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to thank them all by name, but I have the deepest gratitude to each of the students who challenged me daily. I also want to extend my immense gratitude to Nathan Dudley and Murray Fisher for entrusting me with the responsibility to build Harbor’s math program. They gave me the most meaningful and enriching professional experience of my life, which greatly informed this dissertation.

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Chapter 1: A Study Overview

1.1 Introduction

This dissertation is a quantitative study about being and not being a “math person.” On a recent nationally representative survey, over 21,000 ninth grade students were asked whether they see themselves as math persons and if they agree that others see them this way. Combined by principal component factor analysis and standardized to a mean of 0 and a standard deviation of 1, \textit{personal math identity}, how one sees oneself, and \textit{social math identity}, how one believes others perceive them, operationalize mathematics identity for the High School Longitudinal Study of 2009 (HSLS:09) (Ingels et al., 2011a).

This dissertation examines these constructs from a different perspective. Rather than focusing on mathematics identity as an emergent characteristic, the current study addresses a subgroup of students whose personal math identities and social math identities are in disagreement with one another. This conflict in the personal and social expressions of one’s math identity, hereafter called \textit{mathematics identity dissonance} (MID), is a construct that has not received adequate attention in the research that focuses on student experiences with mathematics.

Researching mathematics identities invites a particular theoretical lens to view mathematics education. School mathematics is a \textit{Discourse}$^1$ (Gee, 2003) that extends beyond elements and operations, properties and theorems, to include beliefs, activities,

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$^1$ Gee distinguishes between discourse with a small “d” and Discourse with a capital “D”. Small “d” discourse refers to spoken and written language. Capital “D” Discourse includes the social context where language takes on meaning.
structures, and practices that are socially situated and distinctive from outside-of-school and professional mathematics Discourses. Situated in school mathematics Discourse, being a “math person” is a socially meaningful identity construct that has been shown to affect performance and future participation.

Math identities are a product of how individuals view themselves, and how they perceive others view them as math persons. Numerous factors contribute to math identity that at first glance may seem to exist outside of mathematics. Some of these factors include other identities like gender, race, and socioeconomic status. Other factors like prior math achievement and math self-efficacy beliefs have a more obvious connection to math identity. In previous research, it is unclear how these factors affect personal math identity and social math identity differently. The current research addresses this issue by examining student characteristics, achievement measures, and mindsets that influence MID expression.

What does it mean to be a math person? What does it mean for someone’s personal math identity to contradict their social math identity? What factors significantly affect the probability that MID will be expressed? Are their measurable gender, racial, or socioeconomic differences in the likelihood of MID expression? How does math ability and prior math achievement affect the disunity of one’s math identity? What other attitudes and beliefs about math and school in general change the odds that MID is expressed? Finally, what are the implications of these dissonant identities for future participation in mathematics Discourse? This dissertation investigates these questions as they apply to ninth grade students in the United States.
A theoretical construct of MID will be developed through a review of relevant literature. To operationalize MID, personal math identity will be measured through the endorsement or rejection of the statement “You see yourself as a math person.” Social math identity will be measured through the endorsement or rejection of the statement “Others see you as a math person.” Where there is a difference of agreement in these responses, MID is expressed. This construct will serve as the dependent variable in multivariate logistic regression models that measure differences in the probability of MID expression as a function of student-level independent variables. Patterns of MID may shed light on the bias particular groups of students experience when they confront identity challenges through their participation in mathematics.

1.1.1 Statement of Problem. Research on math identity is part of a profusion of recent research that focuses on non-cognitive factors to explain group differences in measured school achievement (Bandura, 1997; Bandura & Schunk, 1981; Catsambis, 1994; Dweck, Walton, & Cohen, 2011; Farrington et al., 2012; Steele, 1997; Pajares & Miller, 1994; Oyserman, 2012; Pintrich, 2000). Much of past research on the achievement gap has implicitly equated school success with a hierarchy of cognitive ability (Martin, 2009). Research on the impact of non-cognitive factors illustrates that behaviors, skills, mindsets, and strategies, characteristics not directly measured on content knowledge exams or IQ tests, are critical to academic outcomes (Farrington et al., 2012). Among these non-cognitive factors, academic identities have garnered significant attention in the literature. In numerous studies, academic identities, in concert with other aspects of student identity, have direct effects on academic performance and persistence.
(Cass, Hazari, Cribbs, Sadler, & Sonnert, 2011; Correll, 2001, 2004; Dweck et al., 2011; Oyserman, 2009; Steele, 2010).

Students’ academic identities manifest uniquely in the context of learning mathematics because of the widespread assertion in the United States that mathematical intelligence is innate rather than learned (Anderson, 2007; Dweck, 2008; Steele, 2010). It is common for students to assert, “I’m just not a math person” (Goldin, Epstein, Schorr, & Warner, 2011; Rattan, Good, & Dweck, 2012). Mathematician Steven Strogatz has spent years talking to people about their emotional response to math. He observes half-jokingly that people are traumatized recalling the point at which they realized they were not a math person (Strogatz, 2014). This is often the point when they stopped pursuing math. Others find their math identity spurs them to accomplishment. Math education researcher Shabnam Kavousian recalls her high school years, “when the results came back, I got 95-100% on all my math courses…That was the point that I knew I am a math person…That caused my attraction to mathematics as a career” (Kavousian, 2008, p. 4).

Mathematical prowess aside, some groups have easier experiences identifying as math persons than others. Research on the impact of stereotype threat has shown that the general belief that math skills are inherent and favorable to particular races and genders, namely White and Asian males, affects achievement at the individual level. Numerous studies have shown that when people are reminded of a part of their identity that is negatively stereotyped in mathematics, their performance on mathematical tasks suffers (Oyserman, 2009; Spencer, Steele, & Quinn, 1999; Steele, 1997; Steele & Aronson,
1995). Stereotype threat studies demonstrate that positively identifying with mathematics is critically important to persistence and success in mathematics and math-related fields.

In the United States, mathematics is a gatekeeper subject (Martin, Gholson, & Leonard, 2010), a requirement throughout childhood and adolescence that determines future opportunities (Bryk & Treisman, 2010). The New York City Department of Education illustrates how mathematics serves as a gatekeeper. As the largest school district in the country it requires beginning in the 3rd grade that all students take standardized math exams. Based on these annual exams, students are assigned an institutional identity. These labels—a one, two, three, or four—are shared with students and determine whether an individual can progress to the next grade. “Well below proficient” and “insufficient” are descriptors attached to ones. “Excel” and “more than proficient” are descriptors attached to fours (NYS Testing Program, Performance Level Descriptors).

By 5th grade, the lower integer distinctions limit the middle schools students are eligible to attend. The testing ritual continues in grades six through eight. Each year students face a possible crisis. Will I be a one or a two? Stereotype threat research highlights the additional emotional duress that female and minority students confront in these testing practices (Spencer et al., 1999; Steele, 1997; Steele & Aronson, 1995). The added pressure from the risk of confirming a negative stereotype about one’s group has

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2 The author of this dissertation spent a decade, 2003-2012, teaching high school mathematics in New York City Public Schools. While field notes from that experience are not included in the current study, the experience working with students greatly informs the present work.

3 Beginning in kindergarten, a multitude of screened schools and programs exist in the NYC Department of Education. Eligibility varies and may be based on achievement data, test performance, or auditions.
the potential to significantly hinder performance for the majority of New York City public school students (Spencer, et al., 1999; Steele, 1997; Steele & Aronson, 1995).

Towards the end of middle school, the score from the eighth grade exam influences the high schools an individual is eligible to attend. Once in high school, students are tracked based on their incoming math designation. Regardless of this designation, the New York State Algebra Regents exam, a three-hour test offered once every January and again in June, is a high school graduation requirement. Without achieving the minimum passing score, students cannot receive a high school diploma.

Students on track to graduate and apply to college will likely take the math component of the Scholastic Aptitude Test (SAT), which assigns students a standardized score relative to every other SAT-taking student in the world. The score partially determines the range of post-secondary opportunities available to students.

SATs aside, the majority of NYC high school graduates going on to college enroll in the City University of New York (CUNY). Upon admission, they are required to take a math placement exam. Low performance on this test leads students to noncredit-bearing, remedial math courses. These classes use up valuable and limited federal and state financial aid. The vast minority of students that manage to advance out of remediation and graduate from college are once again confronted with standardized math tests, if they wish to go on to business school, medical school, or any other graduate program.
As a result of their participation in mathematics, each year hundreds of thousands of young people are deemed “insufficient,” “underdeveloped,” or “in need of remediation.” Education opportunities are truncated for those groups who are subordinated to the lowest rungs of a mathematics ability hierarchy (Martin, 2009). These designations track students away from STEM careers and into lower paying jobs (Oakes, 1990).

Historically, females and non-Asian minorities have been left out of many of the opportunities that success in mathematics affords. Under-representation of these groups in math and math related fields continues today (Martin, 2009, Catsambis, 1994; Oakes, 1990; Hill, Corbett, & St. Rose, 2010; Lubienski, 2002). Cognitive explanations are insufficient to explain these disparities. Social structures exist that privilege certain groups over others. A meaningful lens to view these structures is found in the identity perspectives of people at the margins (Collins, 1986).

The power assigned to measures of math proficiency transforms disparities in math education into disparities in education opportunity writ large, disparities that persist along race, gender, and socioeconomic status lines (Boaler & Greeno, 2000; Martin 2009). Math achievement is an important factor that determines career success, income, and psychological well-being (Paglin & Rufolo, 1990; Parsons & Bynner, 2005; Rivera-Batiz, 1992; Rose & Betts, 2004), yet women and non-Asian minorities are significantly underrepresented in upper-level math courses (Hill, Corbett, & St. Rose, 2010; Lee, 2002; Lubienski, 2002; Maple & Stage, 1991; Oakes, 1990). The complex ways in which students perceive themselves in the context of mathematics is critical to understanding
how to increase participation of groups of people underrepresented in mathematics and math-related fields.

1.1.2 Rationale. According to the United States Department of Commerce (Langdon, McKittrick, Beed, Khan, & Doms, 2011), science, technology, engineering and mathematics (STEM) occupations are growing at a rate more than double other industries. STEM workers earn 26 percent more than their non-STEM counterparts, while STEM degree holders can expect higher earnings regardless of whether they work in STEM related occupations (Langdon et al., 2011). In a world increasingly dependent on technology, STEM industries are emerging as the cornerstone of the global marketplace. Yet numerous academic hurdles still exist for historically underrepresented communities to actively participate in this economic boon, not the least of which is advanced mathematics attainment.

While numerous studies show male and female students perform at equal levels through high school (Chipman, 2005; Halpern, Wai & Saw, 2005), women remain underrepresented in upper-level math courses and math-related careers (Hill, Corbett, & St. Rose, 2010; Nosek, Banaji, & Greenwald, 2002). Some have argued that high school girls’ perception of being less proficient than boys in math leads them away from STEM majors and careers (Correll, 2001; Riegle-Crumb & King, 2010). Others attribute female decreases in math performance and participation to stereotype threat (Spencer et al., 1999). Focusing on expressions of MID can contribute to pinpoint sources of females’ proficiency beliefs and stereotype threats in their personal psychology and social
environment. MID research can expose differences in internalized and projected perceptions of being a math person that predict future participation.

Oakes (1990) showed that beginning at a young age, Black and Hispanic students are systematically denied opportunities and disproportionately distributed into lower tracks of math ability. This results in under-representation of racial minorities in college math and beyond (Oakes, 1990). While much research focuses on racial comparisons and measured achievement gaps between races, recent work has begun to explore student values and beliefs about ability to participate meaningfully in mathematics. Examining student attitudes and beliefs offers an alternative to achievement comparisons. Without neglecting persistent structural gaps in educational opportunities, identity research illuminates pathways into and away from heightened participation in math and math-related fields for under-represented minority students (Martin, 2012).

Research shows that strong math identities lead students to higher levels of performance and participation (Cass et al., 2011; Hyde, Fennema, Ryan, & Frost, 1990; McGee & Martin, 2011). Disidentifying with math may lead students away from continued math learning (Catsambis, 1994; Spencer et al., 1999; Steele, 1997). Despite an abundance of recent research focused on math identity, studies have neglected those cases where personal math identity conflicts with social math identity. This dissertation addresses this absence in the literature through a quantitative analysis of MID.

Math identity is a powerful construct to understand math persistence and achievement (Anderson; 2007; Boaler, 2000; Boaler & Greeno, 2000). Prior studies of student mathematics identities, however, presuppose that personal math identities (i.e.,
how students see themselves as math persons) and social math identities (i.e., how they believe others see them as math persons) are in relative agreement. What about when there is a disconnect in the personal and social aspects of math identity? What causes this dissonance? How may this dissonance shed light on the varied gendered and racialized experiences of math students? What can this dissonance tell us about the distinct struggles that students face in developing an identity that results in success in mathematics? This dissertation fills a void in mathematics identity research by grappling with these questions through an investigation of the factors that contribute to the formation of math identity dissonance, the conflict between a student’s personal and social math identity.

1.1.3 Contribution to the Field. Education researchers have used the construct of math identity to ask why a disproportionately small percentage of STEM jobs are filled by women and non-Asian minorities (Black et al., 2010; Boaler & Greeno, 2000; Martin, 2006; Steele, 2010). There has been, however, a paucity of research that investigates differences in the two interconnected yet distinct characteristics that operationalize math identity for quantitative research: personal math identity and social math identity.

Are you a math person? Do others see you as a math person? For most ninth grade students in the United States the answer to these two questions is the same. It is as simple as yes and yes, or no and no. There is a subgroup of the population, roughly 20 percent of students, however, whose responses to the questions concerning the two distinct facets of math identity are different. MID is a measure of this difference.
By interrogating the factors that contribute to MID this dissertation deviates from theories that use math achievement as a measure of intellectual ability. My focus is on social, emotional, and psychological factors that encourage or discourage persistence in mathematics and math-related fields. Examining these factors in a representative sample of students in their first year of high school is especially relevant since student beliefs about school are particularly vulnerable during school transitions (Farrington et al., 2012) and identities are in constant flux (Aronson et al., 2009).

“I see myself” and “others see me” statements touch upon the complex interplay between personal and social worlds in the formation of identity. Social psychologist Glynis Breakwell (1983) states, “the perception of both social and personal identity is most likely to occur when they are in conflict with each other” (p. 10). In the absence of this conflict, the distinction between personal and social identity is not evident, and two identities are in fact perceived as one in the same (Breakwell, 1983). Accordingly, for future studies to differentiate between the impact of personal math identity and social math identity, it is critical to study MID.

In summary, a student’s identity is strongly correlated to math performance, which is understood to be the primary academic gatekeeper to persistence in STEM fields and correlates to economic and emotional wellbeing. As a lens to predict future participation in math and math related fields, identity research offers an alternative to research focused on achievement gaps. Since ninth grade student academic identities are especially vulnerable, the base year of HSLS:09 is an ideal sample for this study. Because a disproportionate number of women and non-Asian minorities are absent in
STEM majors and careers, it begs a critical and nuanced look at math identity at the intersection of gender and race. Though there has been an increase in education research that addresses non-cognitive factors that include math identity, MID is an identity characteristic that has not received adequate attention. Examining differences in MID across variables that include demographics, math achievement, math mindsets, and school mindsets adds to a body of work concerned with improving inclusive frameworks for all students of mathematics.

1.2 Background

What is meant when a student agrees with the statement “you see yourself as a math person” and similarly, what does a young person convey when he disagrees with the statement “others see you as a math person?” In the absence of being able to ask each of the more than 21,000 students who participated in the study how they interpret these questions, a robust theory that draws from theoretical frameworks in education, anthropology, sociology, and psychology is useful in situating this study in a larger body of literature.

1.2.1 Theoretical Framework. William James (1890) recognized self-identity as an integration of self as “knower” and self as “known.” He dichotomized one’s identity as both subject of self (I) and object of others (me). Reconciling these two aspects of identity is far from trivial, especially during adolescence when young people integrate their ideas of being with their sense of becoming (Erikson, 1968). Erikson (1968) illustrates how “the young person, in order to experience wholeness, must feel a progressive continuity… between that which he conceives himself to be and that which
he perceives others to see in him and expect of him” (Erikson, 1968, p. 87). MID is an expression of this struggle in a context with far reaching consequences.

The importance of identity in learning theories is nothing new. Over a hundred years ago, John Dewey promoted education as “a process of living and not a preparation for future living” (Dewey, 1897). His child-centered philosophy recognized learning as both a psychological and sociological process in which “neither can be subordinated to the other” (p. 3). Dewey’s theory that effective learning harnesses the child’s interests and summons her to participate in the life of the community is essential groundwork for developing a theory of MID.

Dewey’s brand of progressive education promoted the idea that learning must become part of the life experience of the child and that “true education comes through the stimulation of the child’s powers by the demands of the social situation in which he finds himself” (1897, p. 3). These “demands” encountered in school mathematics are formidable as they relate to Discourses of power.

Michael Foucault offers a framework for understanding socially designated identities (the me) in relation to Discourses of power. Within a Foucauldian framework, school mathematics reinforces the status quo of inequality, privilege, and class domination by constructing knowledge about students. Foucault likens schools to a ‘learning machine,” at once made to efficiently teach, while simultaneously supervising, hierarchizing, and rewarding (Foucault, 1977). Students’ school activities are highly regulated. They are compartmentalized in individual desks. Their bodies are confined by strict rules of behavior. Their minds are directed to rigid curricula. They are watched
over by teachers. Their academic performance is ranked, registered, and catalogued at every turn. Even handwriting, according to Foucault, is “a whole routine whose rigorous code invests the body in its entirety, from the points of the feet to the tip of the index finger” (p. 152). Schools inculcate and enact the dominant knowledge for students to learn their place, to develop an identity in a social hierarchy. The social math identity assigned to students is a fundamental part of the “knowledge” that school instills, knowledge that to students becomes knowledge of self, part of their identity.

Foucault offers a power-laden framework to develop a theory of MID. When students refuse to integrate the social identities that schools transmit through systems of discipline with their personal identity beliefs, identity dissonance may occur. In this respect, math identity dissonance is a form of rebellion. It is a young person’s psychological struggle against Discourses of power. Foucault (1977) presents us with a critical lens with which to understand schools as disciplinary institutions, and school mathematics specifically as a hierarchizing and normalizing instrument, an imposition that can limit agency and fragment identity.

Dewey and Foucault provide a framework for differentiating and valuing the personal (I) and the social (me) aspects of identities as they come to be experienced and known to students in schools. Likewise, situated theories of learning and identity provide a framework for unifying the personal and social into a single theory of learning as an identity act. In Communities of practice: Learning, meaning and identity, Wenger (1998) ties identity directly to a theory of learning by establishing that:
Learning transforms who we are and what we can do, it is an experience of identity. It is not just an accumulation of skills and information, but a process of becoming—to become a certain person or, conversely, to avoid becoming a certain person. (p. 215)

Within this framework, learning math is the process of becoming a math person, someone who affirms positive identification with mathematics through engagement in relevant activities. Becoming a math person is an evolving form of membership in a math community of practice (Lave & Wenger, 1991). The theories of learning developed by Wenger (1998) and Lave and Wenger (1991) situate knowledge, including mathematics, in social practice. In a communities of practice framework, the learner moves along a continuum of legitimate peripheral participation akin to an apprentice’s development towards mastery (Lave & Wenger, 1991).

Lave and Wenger (1991) acknowledge that within any community of practice there are power relations that mediate levels of peripherality, implying both empowering and disempowering positions. In their theory of legitimate peripheral participation, all community members are implicated in learning. Lave and Wenger, however, recognize that for some, alienation from full participation truncates possibilities for identities of mastery.

A situated learning theory that views math learning as evolving participation in communities of practice places dominant group practices, and the D/discourse that results from them, at the center of its analysis. Gee (2003) defines Discourse as:

A socially accepted association among ways of using language, other symbolic expressions, and “artifacts,” of thinking, feeling, believing, valuing, and acting that can be used to identify oneself as a member of a socially meaningful group or
“social network,” or to signal (that one is playing) a socially meaningful “role.” (p. 131)

Because the claim is that math identities form through participation in communities of practice mediated by school mathematics, it is important to interrogate school mathematics as a Discourse.

Though often considered objective, school mathematics is in fact a kind of cultural knowledge. It is enacted in many social settings, but dominant representations and practices are institutionalized at the exclusion of others (Abreu & Cline, 2003; Gee, 2003; Nasir & Hand, 2006; Nasir, Hand, & Taylor, 2008). While young people encounter mathematics in many different situations, classrooms form the communities of practice through which student participation in math is legitimatized, or de-legitimized, as the case may be. Accordingly, school mathematics can be viewed as a dominant Discourse that facilitates student math identities.

“Identity,” according to Holland, Lachicotte, Skinner, and Cain (1998), “is a concept that figuratively combines the intimate or personal world with the collective space of cultural forms and social relations” (p.5). Contributing to a theory of MID, they provide an identity framework in which:

Self-consciousness and self-reflection develop in the active child as the product of a social history. The person acquires the ability to take the standpoint of others as she learns to objectify herself by the qualities of her performance in and commitment to various social positions. Such objectifications, especially those to which one is strongly emotionally attached, become cores of one’s proactive identities. (p. 4)

According to Holland and associates, students “tell others who they are, but even more importantly, they tell themselves, and they try to act as though they are who they
say they are” (p. 3). Holland and associates describe identities in relation to the stories that students tell.

For MID to be recognized as part of student math identity stories, standpoint theory (Collins, 1986; 2000) is also central to this study. It provides a foundation for valuing student identity stories that form relative to school mathematics. The conflict captured in MID is an expression of recognizing oneself as both an insider and an outsider to mathematics Discourse. Collins (1986) establishes the importance of learning from the “outsider within” perspective, which she argues “may be essential to the creative development of academic disciplines themselves” (p. 15). If math is to be more inclusive for its many different student practitioners, to promote in them a sense of unity in becoming a certain kind of person, then the stories students tell from a MID standpoint must be taken seriously.

Math education researcher, Jo Boaler points out, “theories of identity formation and practice give students an active role in the learning environment, as agents who negotiate, shape, and reflect upon their participation and non-participation” (Boaler, 2000, p. 381). Applying a standpoint framework to this study brings marginalized voices to the center. It assigns theoretical value to the stories young people tell about their experiences with mathematics. Mathematics is a field where standpoints have a profound impact on future opportunities, making standpoint theory essential to this dissertation.

MID expresses a distinct standpoint from which to understand some of the non-cognitive challenges associated with school mathematics. Unpacking students’ experiences in schools, which systematically facilitate the construction of particular
identities, is critical to understanding the function of school mathematics in society.

Focusing on the challenges that young people face in forming coherent math identities adds to theories that recognize disparities in relative measures of math achievement as gaps in opportunities of legitimate participation and identification, not cognitive ability or lack of capacity. Improving the promise that schools will mitigate socioeconomic inequalities depends on understanding and responding to the math identity stories of groups underrepresented in math fields.

1.2.2 Literature Review. Numerous studies have shown that student math identities play a central role in mathematics performance (Boaler, 2000; Boaler and Greeno, 2000; Cass et al., 2011; Oyserman, 2009; Steele, 1997). Math education researchers Grootenboer and Jorgenssen posit, “The goal of learning in the mathematics classroom is the development of students’ mathematical identities – their relationship with the discipline of mathematics” (2008, p. 248). In her discussion of identity-based motivation, Daphna Oyserman (2009) argues for the importance of identity in learning since “people use identities to prepare for action and make sense of the world” (p. 252). Although Heyd-Metzuyanim and Sfard (2011) point out that “identity has no generally adopted operational definition” (p. 130) in mathematics education, a basic and useful definition is found throughout the literature. Math identity is the ways in which we define ourselves and how others define us in contexts of mathematical practice (Anderson, 2007; Grootenboer, Lowrie, & Smith, 2006; Martin, 2009).

Math identity has become an increasingly prominent area of research to explain factors that contribute to group performance and participation disparities in mathematics
and math-related fields (Anderson, 2007; Boaler, 2000; Cass et al., 2011; Martin, 2012). These disparities between groups commonly get referred to as the *achievement gap*.

Though achievement is most certainly influenced by identity, identity is also influence by achievement. As Martin points out, “identity can be used as both an indicator and an outcome for students’ mathematical experiences” (p. 328). This dissertation is concerned with identity as an outcome.

Despite its high stakes for future opportunities, for many 21st century young people math is a language devoid of meaning (Boaler, 2000; Boaler and Greeno, 2000). Mathematics education scholars Boaler and Greeno (2000) illustrate how “many mathematics classrooms, particularly those at higher levels, are unusually narrow and ritualistic, leading able students to reject the discipline at a sensitive stage of their identity development” (p. 171). Their research shows that “traditional pedagogies and procedural views of mathematics combine to produce environments in which most students must surrender agency and thought in order to follow predetermined routines” (p. 171). This combination of psycho-social irrelevance and high-pressure performance has a deleterious impact on positive identity formation (Gee, 2007). When math is presented as an imposed system of thinking, students will naturally rebel.

Claude Steele argues that “to sustain school success one must be identified with school achievement in the sense of its being a part of one’s self-definition, a personal identity to which one is self-evaluatively accountable” (Steele, 1997, p. 613). Steele has examined the effect of *stereotype threat*, i.e., a situation with the potential to confirm a negative stereotype about a particular group (Steele, 1997). His research shows that
when minority and female students are reminded of their gender or race prior to a challenging math task, the emotional stress of looming negative stereotypes causes a decline in performance (Spencer et al., 1999; Steele, 1997; Steele, 2010; Steele & Aronson, 1995).

Stereotype threat is powerful enough to lead students to disidentify with mathematics (Steele, 1997). To reengage students with math, scholars Gloria Ladson-Billings and Eric Gutstein outline the importance of giving students opportunities to integrate their math identities with culturally affirming, positive identities (Gutstein, 2006; Ladson-Billings, 1998). If students practice mathematics in a way that reshapes math-related identities and simultaneously affirms their racial, ethnic, gender, and other identities, they may feel empowered to embrace mathematics as a part of the self, a tool for change (Gutstein, 2003, 2006; Ladson-Billings, 1998; Martin, 2006).

Perhaps because of its dependence on logical reasoning, school mathematics is rarely discussed in the literature as ideological or culturally biased. Education theorists Kincheloe and Tobin (2009) caution, however, when “norms and values go undetected, they exert a profound influence on what passes as objective and rigorous knowledge and what does not” (p. 517). In the case of school mathematics, what gets measured as core, valuable knowledge, and what is considered extraneous, tangential, ethnic, archaic, or arbitrary is essential to continually promoting some students as insiders, while others get pushed further to the margins.

History shows mathematics participation patterned by race and gender. Research focusing exclusively on math achievement gaps implicitly endorses the structures that

Students are under extreme pressure to accept oppressive social identities. Gee writes:

In modern capitalist society nonelites are “encouraged” to accept the inferior identities elites ascribe to them in talk and interaction as if they were the actual achieved identities of these nonelite people, achieved on the basis of their lack of skill, intelligence, morality, or sufficient effort in comparison with the elites (Gee, 2001, p.113).

Using math performance to assign persons inferior social identities is more apparent today than ever before. The proliferation of education reforms that require high-stakes standardized tests, quantitative results, and empirical data subjugate young people to constant surveillance. Employing such data-driven education to promote education equity implies that closing the achievement gap requires marginalized students to embrace hegemonic structures that position them at the bottom of an academic hierarchy (Martin, 2012). Rather than accept achievement gap rhetoric carte blanche, math identity research offers an alternative framework for looking at pathways into and out of STEM fields. The current study does not employ math identity in the service of the dominant ideology of math achievement, but considers the stories that students tell about who they are to be a performance measure unto itself.

Understanding factors that affect student math identity is a central concern of research aimed at boosting participation for communities that have been misunderstood
and underrepresented in STEM majors and careers. Math performance, more than any other academic factor, determines whether students may access STEM majors in college and pursue STEM careers (Sainz & Eccles, 2012). Within math identity literature, student agency is recognized and identity-based motivations become paramount to academic success.

1.3 Methodology

This dissertation adds to an understanding of the complexity of student math identities by analyzing their identity stories as they begin high school as ninth graders. The stories in this case are told almost entirely through students’ responses to a nationally administered questionnaire and analyzed using multivariate logistic regression models.

Logistic regression is a tool to understand changes in the probability of MID expression as a function of multiple independent variables. In this study, four groups of domain variables are included in hierarchical models. Student demographics, math achievement, math mindsets, and school mindsets are all considered possible MID predictors in the study.

Naturally, this methodology poses limitations for investigating identity issues and student stories. Rather than allowing students to tell of their experiences in their own words and from their own standpoints, students are responding to prompts on a four-point Likert-scale. This structure necessarily imposes a narrative, limiting the stories that students are able to tell and narrowing the questions the researcher can ask. While this dissertation will prove internally critical of its own methodology, the benefits of using a
nationally representative sample to examine a theoretically rich and yet unexplored 
construct, MID, far outweigh the study’s limitations.

1.3.1 Procedure

Data employed in the present study are drawn from the first wave of the National 
Center for Education Statistics (NCES) High School Longitudinal Study of 2009 
(HSLS:09). The base year of HSLS:09 surveys a nationally representative sample of 
over 21,000 ninth grade students in 944 schools in 2009. This dissertation will focus on 
the entire population of students who participated in the base year study. Though parents, 
teachers, counselors, and school administrators were also surveyed, this dissertation will 
only employ student level data.

The dependent variable in this study, MID, is established in two ways. Both 
stronger-personal math identity dissonance (MID_p) and stronger-social math identity 
dissonance (MID_s) will be analyzed. MID_p represents an individual who personally 
identifies as a math person, but believes others do not see her or him that way. MID_s 
represents an individual who does not personally identify as a math person, yet believes 
others do see him or her as one. These variables are calculated by finding the difference 
between responses to two consecutive questions: How much do you agree or disagree 
with the statements “I am a math person” and “others see me as a math person”? Logistic 
regression analysis will be used to determine factors that influence the probability that a 
student expresses either form of MID.
Disaggregating MIDₚ and MIDₛ and comparing them to the population where no MID is expressed identifies patterns in MID expression. This study will use separate logistic regression models employing four domains of independent variables. Models will measure changes in the probability of MID based on demographic factors, prior math achievement, attitudes towards math, and attitudes towards school in general. These specific domain variables are based on a review of related research. Because gender shows up in the related research and preliminary bivariate analyses of the data as a significant predictor of MID, analyses of the entire sample and separate analyses of males and females will be conducted. The findings from 24 logistic regression models will be discussed in light of their contribution to related literature.
Chapter 2: Math Identity Dissonance in Theory and Related Research

2.1 Introduction

Heyd-Metzuyanim and Sfard (2011) recognize mathematics learning as the “interplay between two concomitant activities: that of mathematizing – communicating about mathematical objects; and that of subjectifying, that is, communicating about participants of mathematical discourse” (p. 129). They argue that “of all the subjectifying activities, the most consequential for learning seems to be that of identifying – the activity of talking about properties of persons rather than about what the persons do” (p. 129). In a discussion of identity as an analytic lens for education research, James Gee offers a simple definition of identity as being recognized by oneself and others as a certain “kind of person” in a particular context (Gee, 2001, p. 99). Operating from this definition, mathematics identity means being recognized by oneself and others as a “math person” within a mathematics context (Anderson, 2007; Grootenboer et al., 2006; Grootenboer & Zevenbergen, 2008).

Working from this definition of identity is precisely what mathematics education researchers Sfard and Prusak (2005) caution against in their seminal paper that equates identities with stories about persons. They argue that defining identities as “being a kind of person” threatens to promote an essentialist view of identity as an extra-discursive state that is independent of one’s actions and not subject to change. Such a definition threatens to reify math identity as timeless and agentless (Sfard & Prusak, 2005). Yet, without endorsing the belief that math identity is timeless, agentless, or unchangeable, the prevalence of the belief that math ability is intrinsic, a fixed but not universal trait, makes
it a powerful construct (Dweck, 2008; Goldin, Epstein, Schorr, & Warner, 2011; Lerman, 2000). Though math identity cannot be reduced to two simple statements, “I see myself as a math person” and “others see me as a math person,” the endorsement or rejection of these statements will be developed as a critical piece of the stories that are students’ math identities.

There is a long tradition in social psychology that grapples with the individual’s need to integrate internal and external worlds in the process of identity formation. William James (1890) differentiated between the “I” and “Me” of self, recognizing the self as knower and the self as known. Following James, studies in psychology and sociology have differentiated which of these identity elements better predicts behavior (Scheier & Carver, 1983). Some have suggested that social identity precedes the development of a personal identity, and is the greater predictor of one’s behavior (Cooley, 1902; Mead, 1934; Swan, 1983). While, according to Scheier and Carver (1983), others like Freud (1920) and Maslow (1970) believe personal identity to be more primary to the individual and the stronger determinant of behavior.

Erikson’s (1968) analysis of identity favors neither the personal nor the social but portrays identity formation as a dialectic relation that employs simultaneous processes of reflection and observation:

…the individual judges himself in the light of what he perceives to be the way in which others judge him in comparison to themselves and to a typology significant to them; while he judges their way of judging him in the light of how he perceives himself in comparison to them and to types that have become relevant to him” (pp. 22-23).

The statements “You see yourself as a math person” and “Others see you as a math person” are statements about a typology, how one identifies and is identified, within
the context of mathematics. When asserted in the first-person, the statement “you see yourself” is equivalent to “I see myself” or “I am.” When the object of the “I am” sentence refers to being a “math person,” this is an expression of personal math identity, the self as knower. When stated in the first-person, “others see you” statements are equivalent to “others see me” statements. In this case, others are the subject, and the object “me” is assigned the descriptor of being a “math person.” This dissertation calls this expression, social math identity, the self as known.

Whether in psychology, sociology, anthropology, history, or education, identity researchers are concerned with explaining why individuals act in different ways in the same situations (Breakwell, 1983; Sfard and Prusak, 2005). Researching math identity dissonance, the points at which personal and social identities diverge, addresses why individual students participate at different levels in a math setting and why groups sharing an identity form particular patterns of performance in the face of school mathematics.

2.2 Theoretical Framework

2.2.1 Conceptual Overview. Though an entire genealogy of school mathematics is beyond the scope of this dissertation, it is important to grind a theoretical lens for understanding MID as part of students’ identity stories about mathematics. These stories are integral to school mathematics Discourse. As self-evaluations, they lend insight to their level of participation in communities of practice (Gee, 2003; Wenger, 1998). As standpoints, they tell us about mathematics itself (Collins, 1986).
I begin by briefly discussing theories of identity formation from social psychology (e.g. Breakwell, 1983; Erickson, 1968; James, 1890). Next, I discuss Dewey’s child-centered theories of learning, which coincided with the proliferation of high schools in the first two decades of the 20th century. I use Dewey’s emphasis on student interest and self-determination in the learning process to establish the significance of the statement “I am a math person.” Following this discussion, I use Foucault’s (1977) theory of discipline to focus on the ways in which school mathematics becomes an instrument of discipline that subjugates young people to a particular hierarchy through which others judge their math identity. Foucault’s historical analysis of school and examinations provides a theoretical context for the statement “others see me as a math person.” Next, applying sociocultural theories of learning (Gee, 2003; Holland et al., 1998; Lave, 1988; Lave and Wenger, 1991; Wenger, 1998), I will examine how the cognitive dimensions of learning mathematics are embedded in the social dimensions where learning is enacted. Sociocultural theory will highlight the inextricability of identity from the learning process. Finally, standpoints (Collins, 1986) understood from a critical race framework in education (Crenshaw, 1989; Ladson-Billings & Tate, 2006; Solorzano & Yosso, 2002) will provide the theoretical underpinning to understand MID as a counterstory, an expression of resistance to the dominant Discourse of mathematics achievement, told from the perspective of marginalized students. Taken together, this framework results in a situated theory of learning math as a deliberate act of becoming and MID as an expression of distinct struggles in that becoming.

2.2.2 I and Me. For more than a hundred years, the fields of psychology (Bandura, 1977; Freud, 1920; James, 1890,) and sociology (Bourdieu, 1985; Cooley,
1902; Mead, 1934) have looked to identity to predict individual behavior. Research in the latter part of the 20th century challenged traditional notions that identities are fixed traits (Breakwell, 1983). Today, identity is widely understood to be malleable according to the social situation. Identity remains a compelling construct for studying the underlying mechanisms that motivate individual action and patterns of group participation. Identities, however, are context specific and ever changing in the dialectical relationship between personal and social consciousness.

William James (1890) recognized the intrinsic dialectics of being both the knower and the known in identity formation. This exchange between individual and social worlds in the development of identity addresses what James distinguished as the self as subject (I) and the self as object (me). Vygotsky described a similar tension in learning when he referred to mind-in-society-in-mind, the dualism by which individuals shape society, which in turn shapes the individual (Lerman, 2000). Applying this subject object dialectic to education, Vygotsky (1978) recognized learning as the internal reconstruction of external objects. From James to Vygotsky, Western thought has had a long tradition of overcoming the distinction between identity (and learning) as an inherently internal versus distinctly social phenomenon. Resolving that they are both complicates the study of how personal and social identities interact in the individual to influence action.

At any given moment, individuals evoke multiple and overlapping identities depending on the social interactions, institutions, and affiliations they find themselves in (Crenshaw, 1989; Gee, 2001; Holland et al., 1998). In Identity Youth and Crisis (1968), Erikson argues that the young person negotiates personal and social identities to achieve
a sense of inner identity, of wholeness. When adolescents are unable to reconcile their personal and social identities, they may disassociate completely from the context where they experience this dissonance (Erikson, 1968). MID is the expression of this conflict within mathematics education. A theory of MID must establish the meaning of the statements I am a math person and others see me as a math person, while accounting for contradictory forces that cause a discontinuity between the “I” and “Me” in the practice of learning math.

2.2.3 Thought Experiment Interlude. As an example of the interplay between personal and social identities in a ninth grade math classroom, I offer the following thought-experiment. There is a high school math classroom in an urban school district in the United States where a first-year math teacher leads 32 students in an Algebra I course. During a lesson on radical expressions, a student’s overlapping personal identities as “math person”, race_x, and sex_y are stirred up, and together form an identity axis (Crenshaw, 1989) from which the student decides to risk raising a hand to actively participate. Now imagine that this student offers a particularly thorough explanation as to why the square root of -25 cannot exist. The teacher of race_A and sex_B, eager to move on and believing the student has not been listening, quickly dismisses the student’s answer as incorrect. The student tries to counter to further explain the reasoning, but in doing so their voice trembles, they get visually flustered, and the teacher seizes the opportunity to assert control, saying, “I told you already it’s 5i, you’re not right,” finishing with a sarcastic, “jeeez,” that makes the rest of the class laugh.
Through active participation, the very identities that encouraged the student to participate (Oyserman, 2009) came under threat by the social group (Breakwell, 1983). The students’ subjectivity was threatened in such a way that the student became an object of the group, a wrong element in an otherwise correct and absolute mathematical discourse. The student has been reminded of this before, and nowhere more so than in a recent taking of the eighth grade exam. That exam was what landed the student in this school rather than the screened school down the street where they actually wanted to go.

A few minutes after participating, the student’s head goes down for the remainder of the class. Despite feeling embarrassed and misunderstood, not recognized as the math person they are, this student is resilient. They return to school the next day determined to explain to the teacher that after Googling -25, they discovered that Descartes didn’t accept imaginary numbers either. On this day, however, the teacher is absent, and the substitute hands the class a worksheet with the instructions to “simplify the rational expressions in problems 1-40.”

I end the thought experiment there. Nothing too traumatic occurred. Of course there are correct and incorrect answers in mathematics discourse and students must learn to distinguish between these. However, in school mathematics, students risk being judged, time and again, against structures reinforced by an ideology of right and wrong. Without sensitive instruments that recognize the value of different answers, being wrong threatens students with inferior status. For millions of students, add to the anxiety of being wrong, the pressures that come with the threat that stereotypically you are not quite so smart as the person sitting next to you, that because of your race and/or gender you are
at risk, and that there is a math achievement gap between you and the students in the school across the road.

In this climate, which students are more likely to express discordance in their self as knower and self as known in mathematics Discourse? How will the difference be expressed? How does performance influence dissonance? Are there beliefs and mindsets that are more likely to accompany dissonant identities than consonant identities? Theories alone cannot answer these questions, but they provide context for interpreting differences that will be uncovered.

2.2.4 I am a math person. John Dewey’s child-centered theory of education illustrates the critical importance of self as knower in the learning process (Dewey, 1897, 1913, 1916). He provides a foundation in education theory from which to assign value to the statement “I am a math person.” Though Dewey’s theory of education situates learning in social environments, it will be argued that he considered personal identities the point of embarkation for all learning.

James’s (1890) distinction of the I and Me of identity has a direct corollary to Dewey’s analysis of the educational process as an interweaving of the psychological and sociological in which “neither can be subordinated to the other” (1897, p. 3). The psychological, which for Dewey means the child’s will, powers, and instincts, is, however, the basis of all education, the driving force of learning. Dewey argues that the child should be led to learning by his own impulses, that this learning will give him command of himself. Personal identity is the primary motivator for learning pursuits.
Sparked by a child’s interest, learning for Dewey is not solely a cognitive process but is achieved through social experience in which the child has a meaningful role. As an active participant, the student is “bound up in what is going on; its outcome makes a difference to him” (Dewey, 1916, p. 63). For example, the study of numbers “is effectual in the degree in which the pupil realizes the place of the numerical truth he is dealing with in carrying to fruition activities in which he is concerned” (p. 68). These activities are purposeful when they relate to authentic life experiences. Through identity of interest, students are guided to participation in meaningful activity (Dewey, 1897, 1913, 1916).

It is in defining interest that Dewey makes clear the role of identity in his theory of learning. Dewey sees the “self” as something that is continuously formed and reformed through choice of action. He writes of the “kind of a self,” analogous to Gee’s (2001) definition of identity as “being a kind of person”, which is realized through determination in practice. To Dewey, this “kind of a self” is indistinguishable from interest. “Self and interest,” according to Dewey, “are two names for the same fact; the kind and amount of interest actively taken in a thing reveals and measures the quality of selfhood which exists” (1916, p. 171). In a passage from Interest and Effort in Education (1913), Dewey makes the connection to identity more explicit:

True interests are signs that some material, object, mode of skill (or whatever) is appreciated on the basis of what it actually does in carrying to fulfillment some mode of action with which a person has identified himself. Genuine interest, in short, simply means that a person has identified himself with, or has found himself in, a certain course of action. Consequently he is identified with whatever objects and forms of skill are involved in the successful prosecution of that course. (p. 43)
Interest determines identity relative to some action. This forms the primary impetus for learning in Dewey’s framework.

By making interest the starting point, Dewey places the child’s personal identity at the center of his theory of education. Dewey, however, also believes it is the role of education to guide the interests of the child towards meaningful action. Purposeful education emerges by controlling the social environment to harness the interests of the child (Dewey, 1916). Dewey believes that “true education comes through the stimulation of the child’s powers by the demands of the social situations in which he finds himself” (1897, p. 77). Personal agency on the part of the learner is of utmost importance, but Dewey also recognizes learning as a social process.

In Dewey’s framework, learning is sparked by identity but occurs through participation in society. He views society as “an organic union of individuals” (1897, p.4). Dewey’s idealism for a social democracy shaped his theory of education. He imagined democratic schools that mirrored the democratic society that he longed for (Benson, Harkavy, & Puckett, 2007). Schools as a nurturing social environment, meant to foster student interests while guiding them to valuable participation, are the means with which democracy progresses through the generations. Education is after all, “the fundamental method of social progress and reform” (1897, p. 6). In Dewey’s theory of progressive education, personal identity guides learning.

Dewey’s theory of education envisions child-centered pedagogy leading to self-realization. Through the student’s own interests, she asserts what kind of person she is. The power that fuels learning is a product of children’s personal identity, their self-
determination to participate in society. Schools have the job of creating the social environment for steering and nurturing that development.

Dewey is perhaps the greatest influence in a long intellectual tradition in the United States that recognizes the balance of student agency and a controlled social environment in mediating learning. His understanding that interest leads students to become a kind of self, rather than passive receptacles for knowledge, frames the importance of the statement “I am a math person.” His acknowledgement, however, that “the conception of education as a social process and function has no definite meaning until we define the kind of society we have in mind” (1916, p. 48) necessitates that we turn our attention from Dewey’s concept of schools that reflect an idealized social democracy and begin to bring to light the hierarchizing role that education systems play in forming social math identities in contemporary society.

2.2.4 Others see me as a math person. In unpacking the claim “others see me as a math person,” Foucault (1977) elucidates a framework for considering the interplay between institutional power and personal agency in the formation of social math identity. Foucault replaces the child-centered model of learning that Dewey idealized leading to an egalitarian society with what he [Foucault] calls a “learning machine,” at once made to efficiently teach, while simultaneously supervising, hierarchizing, rewarding, and punishing (p. 147). Foucault and Dewey agree that knowledge arises through participation in the social environment, but beyond that their theories deviate from one another. Knowledge, according to Foucault, cannot develop outside of power relations. “There is no power relation without the correlative constitution of a field of knowledge,”
writes Foucault in *Discipline and Punish* (1977), “nor any knowledge that does not presuppose and constitute at the same time power relations” (p. 27). The knowledge of being an object of others, of being surveilled through the lens of normalizing judgments, is key to maintaining these power relations.

Schools form a particular locus of discipline where math has a powerful function. Explained as disciplinary institutions, schools are designed to reinforce individual social rank through sustained *hierarchical observations* and *normalizing judgments* (Foucault, 1977). Mathematics is extremely powerful in this regard as it is celebrated as absolute, decontextualized truth, an indicator of general intelligence against which all can be objectively measured (Lerman, 2000). According to Foucault (1977), the perfect disciplinary apparatus is “both the source of light illuminating everything, and a locus of convergence for everything that must be known” (p. 173). Mathematics establishes objective truth, which is then used to form truths about students. Walkerdine (1988) argues that in this “regime of truth” math performance is synonymous with cognitive development, and cognitive development in turn becomes a summative description of the child. Math is used as a powerful normalizing tool. More than any other area of the school curriculum, it is used to “sort, stratify, and make ability judgments about students” (Martin, 2012, p. 6).

According to Foucault, “discipline ‘makes’ individuals” (p. 170). It forms identities. Though schools have by no means transcended physical coercion, their most powerful systems of discipline are discreet. Embedded power structures shape participation. The duality of being both the knower and the known becomes a question of
structure and agency. Students are not just assigned a rank relative to every other student in the discipline of school mathematics, but implicitly they learn the value assigned to this rank and, through the power of the social environment, are compelled to accept it as their own. In this regard, mathematics passes from an instrument of power to a kind of mirror for understanding oneself.

Students narrate their mathematical selves through the ways in which they decide to participate or not participate, identify or not identify within the Discourse of school mathematics. Through hierarchical observation and normalizing judgments students learn whether others see them as math persons. Particular instruments exist to institutionalize and inculcate this knowledge of the student to the student. At the classroom level, a teacher’s grading system conveys to a student how his or her participation is valued relative to the teacher and classroom of peers. At the school-wide level, the math course that students are assigned reminds them how they are seen relative to institutional hierarchies. Finally, at the national level, standardized test scores normally distribute students across a hierarchy of mathematical “achievement” and “aptitude.”

As summative assessments, these tests more than anything else convey to students their social math identity. In tracing the history of the proliferation of the examination, Foucault explains how hegemonic testing practices affect a student’s identity:

The examination combines the techniques of an observing hierarchy and those of a normalizing judgment. It is a normalizing gaze, a surveillance that makes it possible to qualify, to classify and to punish. It establishes over individuals a visibility through which one differentiates them and judges them. That is why, in all the mechanisms of discipline, the examination is highly ritualized. In it are combined the ceremony of power and the form of the experiment, the deployment of force and the establishment of truth. At the heart of the procedures of
discipline, it manifests the subjection of those who are perceived as objects and the objectification of those who are subjected. (Foucault, 1977, pp. 184-85)

Because mathematics is reified as some immutable thing, in math education it is students who become the object of study, and math the lens with which others can cast a normalizing gaze.

2.2.5 Dewey and Foucault summarized. Dewey believed child-centered pedagogy that empowered students to act from personal interest would lead seamlessly to upward mobility and democratic participation in society. Foucault illustrates power relations embedded in school institutions that mediate the social practices from which math identities form. Dewey supplies a theory of education that values the statement “I am a math person.” Foucault provides the social context from which to understand the complexities of the statement “others see me as a math person.”

Dewey’s and Foucault’s theories of school and learning lay the foundation to construct personal math identity and social math identity as interconnected yet distinct relations to practice. Sociocultural theory will be used to bring the personal and social back together, to illuminate the interdependence of psychological and social processes in the context of school mathematics, and to construct an integrated theory of MID.

2.2.6 School mathematics discourse situated in practice. Lave and Wenger (1991) propose a theory of legitimate peripheral participation (LPP) in which learners move from apprentices to experts through a process of increasing participation in communities of practice. In an LPP framework, learning math is not a process that is accomplished exclusively through individual cognitive activity, nor are social practices
viewed as pedagogical tools to facilitate individual learning. Rather, learning is embedded in the patterns that make up practice. Knowledge assumes meaning relative to those practices. Learning is an act of becoming, of changing identities along a spectrum of beginner to master. Mathematical knowledge is no exception. Mathematical structures may underlie much of the known universe, but mathematics discourse only takes on meaning within the social practices where it is embedded.

This dissertation adopts Gee’s theory of Discourse to group the practices and beliefs that mediate legitimate peripheral participation in mathematics communities of practice. A theory of Discourse encompasses much more than language. Discourses are ways of being in the world, of acting, valuing, believing, behaving, talking, writing, dressing, thinking, feeling, and performing. Within a meaningful group, Discourses mediate the patterns of social action (Gee, 2003). Gee defines dominant Discourses as those Discourses that in their relation to social power and hierarchical structure lead to social goods in society (2003). As a means of assigning students rank throughout their formal education trajectory, and as a gatekeeper to many future opportunities, mathematics is one such dominant Discourse (Martin et al., 2010).

Calling mathematics a Discourse implies that it is social. What then becomes of the claim that mathematics constitutes an objective body of knowledge, capturing universal truths, concerned only with abstract knowledge, with deductive reasoning, with fact? I do not wish to question the veracity of Hilbert’s geometric axioms any more than I want to enter a philosophical debate about whether theorems in mathematics are created or discovered (Lakoff & Nunez, 2000). The assertion, however, that given its abstract
nature mathematical truth should be understood to be absolute and located outside of practice, strengthens its power to be used as a marker of general intelligence and indicator of cognitive development (Lerman, 2000; Walkerdine, 1988). For some, mathematics certainly is abstract and generalizable, but as Lave and Wenger (1991) illustrate, the “power of abstraction is thoroughly situated in the lives of persons and culture that makes it possible” (p. 34). Regardless of one’s stance on Platonic idealism and mathematical objectivity, there can be no claim of neutrality in the activities of school mathematics, which are by nature political and ideological.

While mathematizing exists in many aspects of life, what gets valued as mathematics among the general population exists almost exclusively in school (Abreu & Cline, 2003; Walkerdine, 1988; Witte, 1995). The mathematics encountered in classrooms is often void of connections to a young person’s life outside of class (Boaler, 2000), yet it is endowed with high stakes for future opportunities (Anderson, 2007). In the United States, school mathematics is largely defined by standardized curriculums and textbook industries. These serve the practitioners, both students and teachers alike, a prescription for normal performance. The prevalence of standardized tests, at every rung of one’s climb through school mathematics, ensures that students and teachers adhere to curricular norms. With the ever looming risk of punishment for those that deviate from the dominant structures of knowledge, school mathematics has been described as narrow and ritualistic, greatly restricting student agency (Boaler, 2000).

Regardless of school achievement, students may participate in many activities that call upon mathematical content and mathematical reasoning outside of school. A young
person may love to play particular videogames organized by geometric transformations (El-Nasr & Seif, 2006); engage in mathematical problem solving in sports (Nasir et al., 2008); find a particular fluency with place value when dealing with money (Carraher, Carraher & Schliemann, 1985; Taylor 2004); or enjoy measuring and proportional reasoning in cooking. All of these practices explicitly integrate mathematical content, yet are rarely valued in dominant mathematics discourse.

In a study of out-of-school mathematizing, Nasir (2000) discovered that a group of high school student athletes accurately calculated percents and averages in a basketball context but struggled when similar problems were presented in a traditional school context. Similarly, Taylor (2004) found children who expressed fluency with place value when using currency to buy candy but not when the same concepts were practiced with base-ten blocks in class. Conversely, Boaler and Greeno’s research (2000) demonstrates the difficulties students encounter using their school mathematics in situations that require a different set of practices but similar mathematics content to what they are accustomed to in their traditional classrooms. Though they had arguably learned abstract, generalizable mathematics, it was not transferable outside of the narrow context in which it is practiced. Each of these examples serves as a demonstration of the inextricability of mathematical knowledge and practice. The difference between in-school and out-of-school mathematics practices influences MID expression.

Before continuing, not only is there a distinction made between out-of-school mathematics and school mathematics but also between school mathematics and professional mathematics (Grootenboer & Zevenbergen, 2008; Lerman, 2000).
Mathematicians, whose practice is creative, open-ended, and often highly collaborative, uncover deep patterns that are at once serious and beautiful (Hardy, 1940). Traditional school mathematics is individualistic and closed (Boaler, 2002). Since a very small percentage of people are ever exposed to the mathematics of mathematicians, school mathematics is what most non-mathematicians identify as math (Anderson, 2007) and therefore is the mathematics Discourse I unpack to arrive at a theory of MID.

Identities, according to Gee (2003), form in relation to Discourses. Young people regularly mesh primary Discourses, those Discourses they come into early in life as members of a family and through peer-group socialization in familiar cultural settings, with secondary Discourses, embedded in larger social structures (Gee, 2003). It is in meshing primary Discourses with the secondary dominant Discourse of school mathematics that MID starts to take shape.

Math identity may be informed by out-of-school mathematizing, but it is through participation in the dominant Discourse of school mathematics, with its accompanying hegemonic practices and ideologies, that “truth” about mathematical development is produced (Walkerdine, 1988), that math identities form (Anderson, 2007). School mathematics invites a field of values that stretches far beyond standard curriculum. It brings with it numerous activities and rituals that restrict identity in practice. Boaler and Greeno (2000) suggest that within the practice of traditional school mathematics “students must surrender agency and thought in order to follow predetermined routines” (p. 171). They argue that many capable students reject these practices because they run counter to their values, to their developing sense of agency and identity. Negotiating a
community of practice where the values of the dominant Discourse clash with values of one’s primary Discourse can result in a conflict of personal and social identity. According to Breakwell (1983), clashing values may cause personal and social identity to come into conflict. In the case of mathematics, this research has constructed MID to operationalize this conflict.

2.2.7 Math identity dissonance explained. In a recent study capturing student resistance to identities assigned to them by external evaluations, a young student Margarita reckoned:

I like to be able to think a certain way, like not somebody telling you, you have to think this way in order to do that. You just think your own way to find out the answer your way. There [are] different strategies, and you can find your own strategy. (Gutiérrez, Willey & Khistey 2011, p. 33)

Margarita’s desire for freedom to act and solve problems her own way can be greatly restricted in traditional school mathematics Discourse. Boaler (2000) writes, “for many students, engaging with such a world requires a serious re-alignment of identity that they are unable or unwilling to make, and research suggests that this is particularly true for girls, working class students, and students from non-dominant cultural backgrounds” (p. 393). Philosopher of mathematics, Imre Lakatos states, “it has not yet been sufficiently realized that present mathematical and scientific education is a hot bed of authoritarianism and the worst enemy of independent and critical thought” (quoted in Witte, 1995, p. 238). Who better to illustrate this for the researcher than the students who experience school mathematics every day?
Student assertions of being a math person despite believing others don’t see them that way are an expression of resistance to assigned identities in a Discourse that they commonly experience as authoritative. Similarly, a student who disavows the positive math identity others assign is indicating that, at least on a personal level, she feels disconnected from practice. These expressions of MID, stronger-personal math identity dissonance (MID_p) and stronger-social math identity dissonance (MID_s), form the opening lines of underexplored stories about students’ active struggles to identify within mathematics Discourse.

Sfard and Prusak (2005) propose operationalizing identity in math education research by equating it to the stories that students tell. These stories are often considered meaningful for what they can tell the researcher about the underlying mechanisms that affect math achievement. I conceptualize the current research in math identity dissonance with a goal to learn about learning from student standpoints. MID is part of the stories that counter purely achievement-focused narratives. Critical race education scholars Solorzano and Yosso (2002) define the counterstory as “a method of telling the stories of those people whose experiences are not often told (i.e., those on the margins of society)” (p. 32). Gutiérrez et al. (2011) apply this concept to math education research as the “stories that illuminate the conditions of schooling and perhaps challenge accepted assumptions about schooling practices, particularly those related to mathematics” (p. 27).

As part of a counterstory, MID expresses a standpoint of one who is both an insider and an outsider in the Discourse of mathematics. The outsider within (Collins, 1986) perspective out of which MID is constructed provides valuable standpoints to
understand student agency as they regularly assess their own participation and performance. Marginalized voices illuminate practices and ideologies that can otherwise be taken for granted. Where learning is an act of identifying, MID may be an expression of the meta-cognitive awareness of not belonging, which can lead students away from mathematics no matter what their achievement levels.

In addition to serving as a counterstory, MID is a lens through which to better understand personal and social identities as interconnected yet distinct in action. As Breakwell writes:

… the perception of both social and personal identity is most likely to occur when they are in conflict with each other. When a person finds his or her social role demands one course of action and his or her personal feelings call for another course of action, the individual becomes aware of both personal and social identity. The interesting thing is that at other times the distinction is not made. When conflict does occur, however, the dualism is immediately evident. (Breakwell, 1983, p. 10)

Navigating school mathematics Discourse, students are confronted with complex, hierarchical structures replete with distinct social practices, standardized curriculum, and dominant forms of knowledge from which they construct their math identity. In the following section, this dissertation will explore the literature in search of concrete variables that influence different forms of math identity dissonance.

2.3 Literature Review

2.3.1 Introduction. In her discussion of identity-based motivation, Oyserman (2009) argues for the importance of identity in learning since “people use identities to prepare for action and make sense of the world” (p. 252). Although math identity has become an increasingly prominent area of research to explain non-cognitive factors that
contribute to the so-called “achievement gap” (Anderson, 2007; Boaler, 2000; Martin, 2012; Spencer, Steele, & Quinn, 1999; Steele, 1997). Gutiérrez notes “few studies using large-scale data sets move beyond issues of access and achievement to capture broader notions of mathematical identity or power” (Gutiérrez, 2008, p. 360). In addressing this paucity of research, I use a nationally representative dataset to investigate factors that contribute to math identity dissonance (MID).

2.3.2 Overlapping Identities. Identities are multi-faceted and overlapping (Gee, 2003; Holland et al., 1998; Oyserman, 2009), and individual identities are cued, challenged, and regularly reconstructed through participation in different Discourses (Gee, 2003). Math identity is no different. It need not be fixed, but comes to be known in relation to particular social practices where multiple relevant identities intersect. The saliency of math identities is nowhere more apparent than in school mathematics, where students participate in math classroom communities of practice.

2.3.2.1 Math identity and gender. Though numerous intersecting identities may come to bear on personal and social math identities, research has shown that gender is particularly salient in the construction of those identities. In the United States there are pervasive stereotypes that males are better than females at math, and mathematics ability is a male trait (Aronson & Steele, 1995; Caplan & Caplan, 2005; Chipman, 2005; Davies & Spencer, 2005; Eccles, Jacobs, & Harold, 1990). The male-math superiority stereotype has far reaching consequences on the achievement-related beliefs (Hyde et al., 1990; Nosek, Banjai, & Greenwald, 2002) and math performance (Oyserman, 2009; Spencer et al., 1999) of students.
Nosek and colleagues (2002) found that despite research that demonstrates widespread rejection of gendered math-stereotypes by both males and females (Hyde, Fennema, Ryan et al., 1990), women have stronger negative evaluations of math. Nosek and colleagues employed a response completion task called the Implicit Association Test (IAT) to measure math attitude, math identity, math-gender stereotypes, and gender identity. The IAT operates under the assumption that it should be easier to pair concepts that are more strongly associated. For women in the testing pool, stronger math + male associations signal weaker math identity. For men, the exact opposite is the case. Stronger math + male associations should be associated with stronger math identity. Nosek’s study found that both women and men paired math + male more easily than math + female, illuminating implicit gender stereotypes and stronger math identity for men and weaker math identity for women. The Nosek et al. study posits that explicit rejections of math-gender stereotypes are consciously egalitarian self-reported measures that neglect to report underlying bias. The IAT results show unreported stereotypes persist⁴.

Additionally, Nosek and colleagues (2002) studied in-group gender identifications and found that women with stronger female gender identity were associated with more negative math attitudes. Schmader (2002) showed similarly that in a situation where gender identities were cued prior to a math task, women with stronger gender identities performed worse than women who did not feel gender was central to their self-concept.

⁴ Not all research shows groups rejecting gender math stereotypes. As an example, 45% of students in an introductory psychology class at Stanford reported holding the belief that women have less math ability than men (Pronin et al., 2004). Regardless, stereotypes need not be endorsed for the threats they pose to take hold (Spencer, Steele, & Quinn, 1999).
Pronin, Steele, and Ross (2004) showed that women who strongly identified with math disavow stereotypically feminine traits associated with relevant negative stereotypes in a math context. So although gendered math stereotypes may be outwardly rejected in survey responses, research in stereotype threat shows that, at least subconsciously, these beliefs and the threat associated with them continue to appear, forcing women and men to continuously negotiate their identities at the intersection of gender and mathematics.

The power of negative stereotypes comes to light by harming performance and constraining pathways to ongoing participation in mathematics and math-related fields for those who experience the stereotype as a threat (Eccles, 1987; Oyserman, 2009; Steele, Spencer, & Aronson, 2002). Stereotype threat is the sense of being judged in light of a negative stereotype about a group that one is a part of, in meaningful situations that cue the negative stereotype, that invite the threat of performing in a way to confirm it (Steele, 1997, p. 616). For women practicing mathematics, studies over the last 15 years confirm negative effects of gendered stereotypes on performance (Davies & Spencer, 2005; Oyserman, 2009; Spencer, Steele, and Quinn, 1999).

Spencer, Steele, and Quinn (1999) showed females underperformed relative to males in different math testing situations that cued negative stereotypes. In a preliminary study, Spencer and colleagues administered a relatively easy math test and a sufficiently advanced math exam to a highly selective group of male and female college students to test previous findings that females and males with similar prior math achievement levels will perform equally well on simpler math tests but that females will underperform on more difficult math tests. Spencer et al. (1999) confirmed this pattern, but where
previous literature explained these results in genetic differences between men and women (Benbow & Stanley, 1980) or gender-role socialization (Fennema & Sherman, 1977; Eccles, 1987), Spencer and colleagues were interested in an explanation based on stereotype threat.

To test the presence of stereotype threat, Spencer and colleagues conducted two more studies. In the first, they administered a similar advanced math exam to two different groups of high achieving male and female students. To ensure that gender stereotypes were relevant in the testing situation, one group was told prior to taking the test that the test had shown gender differences in the past. To test the impact of stereotypes, however, the second group was told that the test had never shown gender differences, making the stereotype irrelevant. In the first group where the stereotype was relevant, female students greatly underperformed. In the second group, where the stereotype was made irrelevant, no performance differences among females and males were measured (Spencer et al., 1999).

In a third study, Spencer and colleagues included a control group in which no mention of gender performance was made. The results from the previous study were replicated. Women underperformed relative to men in the control group where researchers made no mention of gender differences, but where researchers specifically stated that there were no differences between male and female test results, no differences were measured among the male and female test-takers. As was the case in the first study, Spencer and colleagues explained that the cognitive demand of the more challenging mathematics cued negative stereotypes, which in turn, invited stress and arousal that
detracted from performance. These results confirmed that women’s performance increased when stereotype threat was removed from the testing situation (Spencer et al., 1999).

The deleterious effect of stereotype threat has been shown to have the most severe impact in domains where one strongly identifies (Aronson et al., 1999; Steele et al., 2002). As a means to defend against stereotype threat, people may disidentify with the domains in which the stereotype applies (Spencer et al., 1999; Steele, 1997; Steele et al., 2002). For female students and others who belong to groups that are perceived as less mathematically capable, rejecting a positive personal-math identity lessens the stereotype threat. This explains findings that boys’ math ability self-concepts are consistently higher than those of girls’ (Catsambis, 1994; Wigfield et al., 1997). Catsambis (1994) used nationally representative data to show that by the eighth grade girls show less interest in math and more negative attitudes towards the subject. In general, Steele (1997) proposes that instead of reflecting real self-concepts, assertions that seem self-rejecting may actually be self-preservation strategies to protect against negative stereotypes.

Gender discrepancies in self-reported competence beliefs may also be a result of social conditioning in which it is less acceptable for females to express high levels of confidence in mathematics (Chipman, 2005). Chipman argues negative stereotypes are perpetuated in research that inaccurately casts women’s math participation and accomplishments as inferior to those of men. Chipman uses 30 years of data from NCES, NAEP, and other nationally representative studies to show that women’s achievement...
and participation in math at the undergraduate level are consistent with their general achievement and participation in college. Though there is certainly underrepresentation in some math-related fields, namely engineering, physics and computer science, to all of which math serves as a gatekeeper, Chipman makes a compelling case that there are no measureable sex differences in mathematics performance prior to secondary school, nor any sex differences in regards to gender distribution of college math majors (Chipman, 2005).

Where there are measured differences in performance, as is the case with the widely cited difference in male and female average SAT Math scores, Chipman (2005) argues that the SAT math exam under-predicts the performance of females in college math and may be interpreted in light of stereotype threat as a self-fulfilling response to the testing situation. Chipman argues that females, knowing what the data say, are under considerably more stereotype threat than in other settings. Chipman asserts, “the primary women in mathematics problem in the U.S. today is that people keep talking about the women and mathematics problem” (p. 19). Though this certainly may be true in relation to performance and achievement levels, it remains important to investigate generalizable differences in math identity construction between males and females. MID may shed light on how stereotypes are experienced and how social conditioning is internalized. In light of the literature on gender and math identity in practice, which shows that despite mostly equal achievement measures, females express less interest and weaker identification with math, this dissertation hypothesizes that female students are more likely to express stronger-social math identity dissonance than their male counterparts.
2.3.2.2 Math identity and race. Gutiérrez (2008) and Martin (2012) make arguments similar to Chipman (2005) regarding “achievement gap” research that perpetuates racial hierarchies in mathematics. Gutiérrez argues that “gap gazing” mathematics research “supports deficit thinking and negative narratives about students of color and working-class students (Gutiérrez, 2008, p. 358). She argues that an achievement-gap lens reifies whiteness as the norm by which to normalize the “lower achievement” of students of color. Martin (2012) cautions that such research supports the conceptualization of mathematics learners in a racial hierarchy where students of color are rendered change worthy relative to their White counterparts. Martin contends that not only is race socially constructed but “racial gaps” in mathematics achievement are also “socially constructed and contingent” (p. 300). Martin illustrates how mathematics classrooms are highly racialized spaces that students must navigate while co-constructing their racial and mathematics identities.

In her dissertation study of high achieving Black college and graduate students in mathematics and engineering, McGee (2009) reveals two main motivations for their resilience in mathematics. The first main trajectory she observes is resilience to defend oneself against externally generated criteria, to continue achieving to prove racial stereotypes wrong. This she names “fragile resilience,” which she observes in in-depth interviews as an early form of resilience. As students mature, she observes a pattern where fragile resilience transforms into “robust resilience.” Those who possess robust resilience use it to serve as a role model for others. The motivation to prove stereotypes wrong, as was the case with fragile resistance, situates one’s math identity externally, in
the social field where those stereotypes persist. Serving as a role model, in turn, situates math identity internally, in the personal identity of the individual (McGee, 2009).

McGee’s model illustrates implicit expressions of MID as students pass from fragile forms of resilience in early years of schooling to robust forms of resilience in the later high school years and into college. As students persevere through their math education, their math identities pass from being externally to internally situated. In McGee’s interviews, we see expressions of MID serving to motivate student success. In one in-depth interview we hear from a participant:

It’s definitely been a driving force of mine because I get a certain amount of satisfaction sometimes being the only African American in the class because, inside my own head, I don’t even know if there’s people in the class that think like this, but inside my own head I figure that there are people like, “Who’s the Black kid at the back of the class? What’s he doing here? He doesn’t belong here.” And like I said, it drives me forward knowing that there are people out there that think like that and I get to prove them wrong – ha-ha (p. 98).

McGee finds patterns of others don’t see me as a math person, but I’m going to prove them wrong across her subjects’ early schooling experiences. The others in this case included teachers, school administrators, and peers, but more powerful than any actual person were the omnipresent negative societal stereotypes that Black students have to contend with. As we see in the student’s quote above, “I don’t even know if there’s people in the class that think like this, but inside my own head I figure there are…” the “others” need not be real people. Threats are transmitted through prevailing social stereotypes, where racial hierarchies in the practice of mathematics are internalized by the participants regardless of whether their immediate surroundings endorse these stereotypes.
Though she asserted that all the participants in her study had strong mathematics identities, she recognized the locus of these identities exist outside of students in their early years. This externalizing of their math identity, according to McGee, left their internal, personal identities less developed. This guiding *prove-them-wrong* motivation, however, transforms in later schooling when the students begin to define their math identities through self-generated criteria. Robust resilience still implies a level of MID, but the locus of identity is one’s personal identity. “I am a math person and I’m going to show others they can be too,” emphasizes one’s personal identity as the guiding motivation, while still acknowledging the challenges that one faces in being recognized by others. McGee’s study shows that as high achieving Black students persist in school mathematics Discourse, issues of identity and agency are central to understanding achievement patterns as responses to racialized hierarchies.

Latino/a youth are also met with prevailing stereotypes of lower math ability. Research and policy that emphasize lower achievement data perpetuate these stereotypes (Gutiérrez et al., 2011; Zavala, 2012). Gutiérrez and colleagues (2011) report that Latinas/os have the lowest achievement levels on math standardized tests. A study using the National Educational Study of 1988 (NELS:88), a nationally representative dataset, found Latinas to be the students with the most negative attitudes towards math and towards their own academic ability (Catsambis, 1994). To counter the stories told by achievement data alone, and to better understand Latina/o attitudes towards math, Gutiérrez and colleagues (2011) used stories from Latina/o student perspectives to uncover a pattern of resistance from students who had a sense of being misjudged in their school mathematics participation. Gutiérrez and colleagues argue that school math for
the majority of Latina/o students is characterized by rote learning rather than the challenging and collaborative problem solving to which their White counterparts are exposed.

Catsambis’s study (1994) supports this assertion, showing that in the eighth grade Latina/o students are disproportionately enrolled in the lowest ability grouping classes, which are widely understood to remediate through rote learning. Gutiérrez et al. (2011) juxtaposes “social arrangements” of classroom mathematics with math practiced as part of an afterschool club. In the clubs that capitalize on student cultural resources and lived experiences, one sees how changing social arrangements provide students with platforms to resist negative math identities imposed on them through the low expectations of others.

In her dissertation study on Latinas/os math identity, Zavala (2012) highlights Latina/o testimonios. Personal accounts of classroom participation provide counterstories that illustrate how students exhibit agency in forming math identities at the intersection of racial, linguistic, and ethnic identities. Zavala (2012) brings to light dynamic identity stories of two Latina/o ninth graders who work together in class. Despite being high achieving in math, Samuel asserted, “I’m just not a math person.” Meanwhile, Julieta, who is not high achieving, loves math. Zavala’s analysis of Samuel and Julieta, like the Gutiérrez et al. (2011) study, shows math identities are regularly fragmented in the major social arrangements of classroom mathematics, which may not account for language barriers or provide culturally welcoming environments (Zavala, 2012).

Asian Americans are the exception in the stereotypical math hierarchy that positions Whites above people of color in mathematical achievement and ability. Where
for African American and females students it has been shown that cuing racial and gender identities prior to a math challenge hinders performance, Asian student performance has been measured to increase when Asian identity is cued prior to a math challenge (Shih, Pittinsky, & Ambaddy; 1999). For a group of high performing Asian American females, Shih and colleagues (1999) showed that relative to a control group, performance was significantly lower for those students whose gender-identities were cued prior to the test. This result was expected based on other studies of the effect of stereotype threat on female performance (Steele, 1997). When Asian identities were cued, however, performance increased by significant margins (Shih et al., 1999).

The Shih et al. (1999) study shows how within a single individual, the identity made salient by testing conditions can both hinder and facilitate performance. In a follow up study, Cheryan and Bodenhausen (2000) showed that cuing Asian identities in ways more explicit than that of the Shih et al. study actually had a negative impact on math performance. They suggest Asian students feel added pressure to confirm positive stereotypes. According to Cheryan and Bodenhausen (2000) the stress associated with performance situations where public expectations of success are salient can actually cause Asians to “choke.”

The Shih et al. (1999) and Cheryan and Bodenhausen (2000) studies show that where race, gender, and math identities intersect, there is no clear deterministic outcome of how an individual’s identity will mediate performance. What is perhaps most important to consider is that mathematics education does not exist in a vacuum but can serve to either affirm or threaten students’ other identities. Sadly, in the case of math
education, identities that students form and have assigned to them too often reify other social hierarchies in society. As Martin (2012) states, “More than any other area of school curriculum, mathematics has been used to sort, stratify, and make ability judgments about students, particularly along lines of race and ethnic background” (p. 6).

At the intersection of school mathematics Discourse and racial identities, many factors come into play. It would seem that to take on positive math identities, students not only have to be affirmed by others in their practice as math students but also feel that those practices complement other aspects of their personal identities. In the face of considerable identity threats, students of color exhibit remarkable persistence in school mathematics. In light of past studies that show Black and Hispanic students maintain positive math identities despite how they are measured against others (Catsambis, 1994; Oakes, 1990) and in light of McGee’s (2009) study that shows a common prove-others-wrong resilience trend, this dissertation hypothesizes that Black and Latina/o students are more likely to express stronger-personal math identity dissonance. Because Asian students are under pressure to confirm positive stereotypes, with which they may not identify, this dissertation expects to uncover Asian students more likely to express stronger-social math identity dissonance.

2.3.2.3 Math identity and socioeconomic status. It is well known that in the United States socioeconomic status is a major predictor of mathematics achievement (Oakes, 1990; Tate, 1997). There is an ample body of literature demonstrating that lower socioeconomic status results in lower academic attainment via identity processes (Bourdieu, 1985; Kao & Thompson, 2003; Oyserman, 2012). Oyserman (2012)
contends, “since people like oneself often fail to finish high school and rarely finish college, such school successes may come to feel identity incongruent and as a result, children of low-income parents may ‘select out’ of school, focusing on identities that do not involve school” (p. 182).

In a study of schools of different SES, Jean Anyon (1980) illustrated how lower SES students were often led in rote, procedural tasks, which stood in direct contrast to the educational environments of higher SES students who were encouraged to collaborate and think critically. These findings have been similarly reported in qualitative research comparing math classrooms along socioeconomic lines (Gutiérrez et al., 2011). Reductionist math practices found in lower SES classrooms have been attributed to students rejecting positive math identities (Boaler, 2000).

In his ethnography, Learning to Labor, Willis (1977) captures working-class boys affirming their working-class identities by resisting bourgeois culture and prevailing ideologies. According to Willis, it is not just schools that facilitate the reproduction of socioeconomic hierarchies, but youth reproduce themselves in opposition to dominant societal structures. In this sense, working class youth might be more likely to dismiss inferior identities assigned to them by school institutions. Willis writes, “there is an element of self-damnation in the taking on of subordinate roles in Western capitalism. However, this damnation is experienced, paradoxically, as true learning, affirmation, appropriation, and as a form of resistance” (p. 3). Considering Willis’s analysis, it would not be surprising to observe an increased likelihood of lower SES students asserting themselves as math people while rejecting negative evaluations by others.
On the other hand, Steele (1997) has argued that disidentifying with particular practices in which one’s group belonging is marginalized can be interpreted as a protection against stereotype threat. Croizet and Claire (1998) show that lower SES students experience significant stereotype threat in completing intellectual tasks. As is the case with women and non-Asian minorities, lower SES students who negotiate their different identities in forming a coherent math identity come under considerable threat. These findings imply that lower SES students are less likely to identify as math persons, and therefore less likely to express stronger personal math identity dissonance.

Another consideration is that high SES parents are more likely to leverage their resources to advocate for their children’s math trajectories (Useem, 1992). Higher SES parents successfully intervene to ensure their children end up positioned to achieve in math, despite the child’s personal interests (Useem, 1992). This results in the likelihood of higher SES students expressing stronger-social MID.

Ignoring that SES parents are more likely to leverage their resources, it stands to reason that higher SES students have an easier time unifying personal and social identities. This is because as a dominant group, they are reflected in the dominant Discourse of school mathematics (Gee, 2003). This dissertation hypothesizes that as SES increases, the likelihood of either form of MID expression decreases.

2.3.3 Prior Math Achievement. In interviews with students, Abreu and Cline (2003) claim that external evaluations of students’ participation in mathematics result in children’s social math identity developing prior to their personal math identity. When one of the young interviewees in the study was asked why she thought her sister was not
good at math, she responded by alluding to the lower-ability class her sister attended and her sister’s report card which said, “she is not good at Maths” (p. 24). In contrast to her sister, the child interviewed did consider herself good at math. She rationalized this claim through her understanding of how she and her sister were identified by significant others in their community of math practice (Abreu & Cline, 2003). They propose, “since criteria for success in schooled mathematics is externally given (e.g., by a teacher’s judgments, by placing a child in ability groups, etc.), it seems that social identities in mathematics can be based on these external events” (Abreu and Cline, 2003, p. 24). They assert that through these external evaluations, children’s understanding of their social math identity may develop prior to their personal math identity. Perhaps, because this study is based in England and its subjects are younger children, they did not include standardized tests in the list of externally given criteria. Furthermore, their analysis does not take into account that external evaluations are regularly imposed throughout a math education trajectory, and as a result, social identities are dynamic and regularly reconstituted. Nonetheless, Abreu and Cline (2003) offer a compelling analysis of the impact of prior math achievement on the development of social math identity. Based on their research, I expect higher math achievement to correspond with a strong social math identity. Their analysis, however, does not provide a lens for understanding the influence of math achievement on personal math identity.

In her development of identity-based motivation, Oyserman (2012) argues that social identities are highly malleable as people seek identity-congruent behaviors and avoid identity-incongruent behaviors. According to Elmore and Oyserman (2012), “school success needs to feel identity-congruent”. Yet, identity-congruent behaviors and
beliefs are not always confirmed in the literature. It is well documented that Black and Latino/a students retain positive identifications with math despite low levels of achievement and limited access to learning opportunities (Catsambis, 1994; Oakes, 1990). According to Oakes (1990), lower achievement trends of minority students begin in elementary school and persist throughout school, resulting in disproportionate percentages of Black and Latino/a students enrolled in non-academic curriculum tracks by high school. Oakes (1990) traces the pipeline out of math and science fields back to lower achievement in elementary school but finds that even as late as high school, Black students retain their positive attitudes towards math. Meanwhile, Catsambis (1994) reports that despite having the greatest opportunities to learn and excel in math, White females consistently have among the most negative self-beliefs related to math. Contrasting Black and White dispositions towards math begs the question of whether math achievement has a consistent influence on math identity when also considering race.

Black and colleagues (2010) employed narrative analysis to build understanding of the dialectic relation between mathematical identities and outcomes of mathematical activity. Drawing on cultural historical activity theory (CHAT), they view identity as emerging from how one considers oneself in past experiences. According to the CHAT framework, through participation in a vast number of activities, individuals collect many different identities. These identities are hierarchically organized, and reorganized depending on the leading activity (Black et al., 2010). They define leading activities as “those [activities] which are significant to the development of the individual’s psyche through the emergence of new motives for engagement” (p. 55). Leading identities, according to Black et al., are those identities that emerge alongside new motives for
engagement, reflecting a hierarchy of motives. Black and colleagues see leading identities “constantly evolving but simultaneously driving one’s engagement and alignment or misalignment with the cultural models which sustain this identity” (p. 68). Using student interviews, they (2010) were able to focus attention on the reciprocal relationship of identity and action. They argue that a leading identity motivates action, but it is in turn always mediated “through actions which result in an outcome which is more significant than the original motive which induced it” (p. 70). From this perspective, identities motivate outcomes, and subsequently, outcomes motivate identities. Identity and performance are in a constant process of co-construction.

I understand math achievement to be a collection of such outcomes, defined by standardized test scores, classroom grades, and ability tracking. Within the CHAT framework that Black and colleagues (2010) establish, and in light of contemporary educational reform policies, math achievement can be considered a leading activity, a motivation unto itself. A student explains: “When you think about it, it’s a bit of a joke, the fact you’re always working towards an exam and you’re not always even learning the whole thing. You just…churning out the work that you’re going to pass your exam which is good because yeah, you’ve got to pass the exam” (Black et al., 2010, p. 67). Learning outcomes are subsumed by achievement outcomes. Understanding math achievement as a leading activity that shifts students’ motives to engage in math education is important for contextualizing the impact of achievement measures on MID.

Like Black et al. (2010), Martin (2009) recognizes that math identity “is always under construction, and results from the negotiation of our own assertions and the
external ascriptions by others” (p. 326). In the United States, these external ascriptions are institutionalized by way of standardized tests, classroom grades, and ability tracking. Each of these institutionalizations has its own impact on MID. It is clear that higher achievement positively affects social math identity, but it is yet to be seen if personal math identity follows in tow.

2.3.3.1 Standardized Tests. Scores on standardized tests are the most universally recognized math achievement outcome. Numerous studies document math achievement disparities between non-Asian minorities and Whites (Lee 2002; Lubienski, 2002; Oakes, 1990), between females and males (Fennema & Sherman, 1977; Noseck et al., 2002), and between U.S. students and students in other countries (Ginsburg, Cooke, Leinwand, Noell & Pollock, 2005). Under the guise of “closing the achievement gap” there is a national mandate to increase test scores. This mandate has reconfigured the landscape of classroom mathematics. Rote test preparation practices and significant time actually taking tests take precedence over other forms of math learning in many U.S. schools. This is especially true for Black and Latino/a students whose experience in math is too often characterized by reductionist pedagogies (Gutiérrez et al., 2011). In discussing the value of standardized tests, Martin cautions against using scores as an objective measure of ability:

Strong societal beliefs in meritocracy, innate ability, and the objectivity of tests obscure findings that many achievement tests are biased toward middle- and

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5 The federal education policy was introduced when the No Child Left Behind (NCLB) Act was passed by Congress in 2001 and signed into law in 2002. It mandated that every child be tested every year from the third to eighth grades. By 2014, every child was supposed to be “proficient” in mathematics. States that failed to meet testing gains faced harsh sanctions. The Obama administration’s introduction in 2008 of Race to the Top maintained this testing regime by insisting that teachers be evaluated based on student test scores.
upper-class White students because pretest items favoring low-achieving and African American, Latino, and Native American students are often rejected in the test construction process. Using modern psychometric methods such as differential item functioning (DIF), it is possible to construct tests and other assessments that favor African American, Latino, and Native American students. Such a process would not only alter achievement disparities on particular measures and challenge assumptions about the abilities of students but would also reveal how so-called racial achievement gaps in mathematics achievement are sociopolitical constructions. (Martin, 2009, pp. 312-313)

To date, these tests retain their pseudo objective status, assigning students hierarchical social markers in their participation in school mathematics. Students come to understand these hierarchizing labels to be one of the ways they are recognized and looked upon by others.

Reay and Wiliam (1999) used focus groups to explore how children’s perceptions of tests contribute to their understandings of themselves, the way they know and name themselves. In a particularly stark example of how students interpret the standard assessment task, not to be confused with the Scholastic Aptitude Test, a student named Hannah proclaims, “I’m hopeless at times tables so I’m frightened I’ll do the SATs and I’ll be a nothing” (p. 345). After the researcher responds, “I don’t understand Hannah. You can’t be a nothing,” Hannah replies, “Yes, you can ‘cause you have to get a level like a 4 or a level 5 and if you’re no good at spellings and times tables you don’t get those levels and so you’re a nothing” (p. 345). This vignette is one example of how examinations create and reinforce the hierarchical classifications, which they may choose to accept or reject in their formation of math identity, that become part of a student self-knowledge.
Though high-stakes standardized tests are by no means new to math education, the federal education policies of No Child Left Behind (U.S. Department of Education, 2001) and Race to the Top (Baker et al., 2010) strengthen their universal hold on the ways in which students are identified. Preparing for and taking standardized mathematics tests have become a recurrent ritual from childhood to adulthood. At every rung of one’s educational trajectory these tests are used as gatekeepers for future opportunities. Test scores are used to separate students in different education tracks. Because the dominant practice of using test scores in math education informs how students are known, I hypothesize that stronger test scores will decrease the probability that students express stronger-personal math identity dissonance. I also hypothesize that students who score poorly on standardized tests will resist the negative identity label associated with their performance and will assert being a math person regardless of how others [the tests] see them. Patterns of this sort of resistance will result in the probability of stronger-self math identity dissonance increasing with lower test scores.

2.3.3.2 “Ability” tracking. Eighty percent of school administrators report that they track their school’s eighth grade math classes (Catsambis, 1994). Boaler (2014) recognizes that in the United States it is common for elementary students to study in mixed ability groupings, but “tracking” remains prevalent in the later middle school years where students can be enrolled in pre-algebra, algebra, or advanced algebra. As we know school transitions to be a time where students’ identities are particularly vulnerable (Aronson et al., 2009; Farrington et al., 2012), it is important to look at how ability tracking in middle school and early high affects math identity dissonance.
In an earlier review of research in education, Oakes (1990) equated lower math achievement in elementary school with the fact that Blacks and Latinos/as are more likely than Whites to be placed in low-ability, remedial, and special education classes. Despite these disparities in opportunity, Oakes (1990) notes that Black elementary school students often express the most positive attitudes towards math of any group. This finding suggests that tracking is not a significant factor determining math identity. Qualitative research conducted by Abreu and Cline (2003), however, suggests that assigning children to ability groups at a very young age could be contributing to a pathway through school that excludes positive social math identities.

Chiu and colleagues (2008) administered a survey to 173 seventh grade students assessing self-concepts, self-esteem, and the kinds of social comparisons that could provide deeper insight into how tracking affects math identity. All 173 participants (86 boys and 87 girls) attended the same school and were distributed among three tracked math courses. Based on their performance on a standardized test, students were placed in a below grade level, at grade level, or above grade level seventh grade math course (Chiu et al., 2008). They measured “math self-concept” through questions about how good students thought they were at math and how they compared to others in their class. They were also asked to compare how good they were in math compared to other school subjects. The survey asked students whether they compared themselves to students in their own classes or in tracks above or below them. The authors found that students compared themselves to other students within their same track than across tracks. Though tracking influenced their math identity, when the effects of grades were controlled, the effects of tracking on identity ceased to be significant. This study showed
grades, rather than math track, had a stronger influence on student math self-concepts (Chiu et al., 2008). From this research and the previous discussion regarding strong math identity despite low level math courses among Black students, it is hypothesized that lower tracks will result in increased odds of stronger-personal math identity dissonance. Because many capable students are placed in higher tracks despite how they feel about math, it is also likely that higher math tracks increase the odd of stronger-social math identity. Considering Chiu’s findings that grades have a stronger influence on math identity than tracking, tracking is likely to have a negligible impact with the inclusion of grades in the current study.

2.3.3.3 Grades. Catsambis (1994) speculates that minority students who express positive self-evaluations regarding their performance in math, despite low test scores, may be judging their performance on the basis of classroom grades. If this is the case, then the Black and Latino/a students in the 1994 study were well ahead of researchers in understanding the central importance of grades for future academic success.

In a comprehensive review of literature about non-cognitive factors that affect school performance, Farrington et al. (2012) found that classroom grades are much better predictors of future educational performance than standardized tests or the courses students take. Farrington and colleagues found extensive research showing “grades students receive have a marked effect on their attitudes about school and about their own academic identities in ways that strongly influence their subsequent behavior and future school performance” (p. 16). From this review of the literature alone, it would imply that
grades may be the best indicator of math identity coherence, both positive and negative, and subsequently would not influence MID.

I hypothesize that grades will not influence MID because more than any other achievement variable, they are contextualized in the actual classroom practices of school mathematics. Class grades emerge out of the same communities of practice as math identities. Farrington and colleagues (2012) explain in their summary of the literature that course grades are the best achievement variable for predicting future academic performance because grades correspond to an array of non-cognitive factors congruent to school success. They develop a model of non-cognitive factors, which they call mindsets. According to their review of the literature mindsets predict grades. Mindsets include perseverance, social skills, learning strategies, and behaviors. Though for “simplicity’s sake” (p. 12) they leave academic identities out of their mindset model, they assume identity “would affect virtually every aspect of the model” (p. 12).

2.3.4 Mathematics Mindsets. Martin (2009) relates math identity to “the dispositions and deeply held beliefs that individuals develop about their ability to participate and perform effectively in mathematical contexts” (p. 326). A wide array of research connects affective variables like dispositions, attitudes, and beliefs to achievement (Pajares & Miller, 1994; Marsh, 1991; McLeod, 1992), but it is not thoroughly understood how theses affective variables influence math identity (Grootenboer et al., 2006).

The affective variables specific to math that are included in this dissertation include math utility, math self-efficacy, and math interest. Each of these falls under the
domain of what recent literature refers to as mindsets (Dweck, 2008; Farrington et al., 2012). Farrington et al. (2012) suggest that “pre-existing academic mindsets” coalesce in a particular “academic identity” (p. 12).

Black et al. (2010) considered student math mindsets important because they “reveal how their identity work makes use of or is mediated by pedagogy” (p. 59). The mindsets considered in this dissertation can all be directly connected to classroom practice. Though beyond the scope of the current literature review, each of these has been studied in relation to interventions to improve math performance. Studying how math mindsets influence MID could prove useful to adapting existing interventions to assist in positive and coherent math identity formation.

2.3.4.1 Math utility. Math utility is the perception that mathematics is useful in everyday life and for college and job futures. Education researchers interested in critical pedagogies (Freire, 1970) and social justice math pedagogy (Gutstein, 2003) have also argued that students should be positioned as agents of change who use mathematics to develop political and social consciousness and positive cultural identities. Martin (2009) includes the ability to use “mathematics to change the conditions of their lives” (p. 326) as a fundamental part of individual math identity.

Beginning with the use of the Fennema-Sherman mathematics attitude scales (Fennema & Sherman, 1976), students’ perceptions of math utility have been researched in numerous studies (Catsambis, 1994; McLeod, 1992; Wigfield & Eccles, 1992). Early findings showed that boys generally have stronger math utility perceptions, which were shown to correlate to stronger identifications with math (McLeod, 1992). In a 1994
study, however, Catsambis showed that despite differences in other affective variables, math-utility didn’t appear to be a factor that shaped students’ other attitudes and beliefs. Nonetheless, it is reasonable to believe that students who do not find the usefulness of mathematics to change the condition of their own life might be more likely to express a negative personal math identity.

### 2.3.4.2 Math Self-efficacy

Since Bandura (1977) proposed the theory of self-efficacy, it has been used widely in math education to show positive correlations between math self-efficacy and math performance (Hackett, 1985; Hackett & Betz, 1989; Pajares & Miller, 1994). Essentially, self-efficacy argues that unless people believe that they can be successful in a task, they have little incentive to act (Bandura, 1986). In other words, self-efficacy “is a context-specific assessment of competence to perform a specific task, a judgment of one’s capabilities to execute specific behaviors in specific situations” (Pajares & Miller, 1994, p.194). Math self-efficacy measures student confidence to successfully participate in the dominant practices of mathematics. Within the HSLS:09 study this scale is based on the confidence to do well on tests, to understand the material of textbooks, to master the skills being taught, and to do an excellent job on assignments (Ingels et al., 2011a). Though math-self efficacy has been shown to have far reaching consequences on student mathematics achievement, there is a paucity of research linking self-efficacy directly to math identity.

Pajares and Miller (1994) show a significant interplay between math self-efficacy and an individual’s perceived competence in math, called *math self-concept*. A student’s
self-worth as a math student, similar to the belief that a student is good in math or feels secure in a math class, is strongly connected to self-efficacy.

It should be noted that the constructs of math self-efficacy, math self-concept, and math identity have significant differences. Self-efficacy is task specific. Self-concept positions students in relation to existing dominant practices of school math. Math identity invites students to reflect on the primacy of math to their own sense of being.

Based on the literature connecting math self-efficacy to both achievement and self-concept, it is reasonable to suppose that students with higher self-efficacy in school mathematics consider themselves to be math people. I base this conjecture on their confidence to execute successfully tasks specific to school mathematics Discourse. Furthermore, because self-efficacy strongly correlates to achievement, I also consider it quite likely that higher self-efficacy generally results in the student belief that others see them as math persons. Therefore, I hypothesize that stronger self-efficacy correlates to a lesser probability that either forms of MID are expressed.

2.3.4.3 Math-Interest. For the purposes of this study, interest in mathematics is a measure of student attitudes towards the domain of school mathematics. Interest is essentially a measure of how much one enjoys math, and how one values math relative to other classes. Dewey’s (1913) framework connecting interest and personal math identity leads to the hypothesis that stronger interest implies the likelihood that a student personally identifies as a math-person. Dewey’s framework says very little, however, about how an individual may be perceived by others in the context of math.

Previous studies have shown that interest affects motivation, which in turn
influences performance (McLeod, 1992; Singh, Granville & Dika, 2002). Like many mindset variables, however, interest has been studied in isolation, and research to show the impact that interest in mathematics has on math identity construction has been inadequate.

This dissertation will measure how interest in mathematics influences MID. Considering the theoretical framework that equates interest to personal identity, I hypothesize that stronger math interest will increase the probability that stronger-personal math identity dissonance is expressed.

2.3.5 School Mindsets. Farrington and colleagues’ (2012) recent review of the literature on non-cognitive factors that affect school achievement brings together a wide body of literature that argues the importance of the affective domain in overall school achievement. Measuring the impact of school mindsets is valuable for assessing whether MID is a local expression of not being recognized in classroom communities of practice, or implies a more global feeling of not belonging to school. It is reasonable to believe that school engagement and school belonging influence the construction of MID.

2.3.5.1 School Belonging. Cohen and Garcia (2008) show how promoting belonging with mathematics classes has a positive impact on identity congruent behavior. Because this study situates math identity in communities of practice embedded in a broader school community, it demonstrates that school belonging is a construct for math identity. Osterman (2000) explains, “the experience of belongingness is associated with important psychological processes. Children… have a stronger sense of identity, but are also willing to conform to and adopt established norms and values” (quote in Farrington
et al., 2012). Other literature posits that this sense of belongingness is a primary human need (Baumeister & Leary, 1995).

The base year HSLS:09 study measures school belonging as a factor of feeling safe, proud, and that there are adults in school to talk to if there are problems. Additional factors considered are students belief that school is meaningful and that it’s important to get good grades (Ingels et al., 2011a). Because school belonging is an indication that an individual has achieved a sense of wholeness in her relation to the social environment, I hypothesize that as school belonging increases, the probability that either form of MID is expressed decreases.

2.3.5.2 School engagement. Engagement in school is defined as active involvement rather than apathy and lack of interest (Lamborn, Newmann & Wehlage, 1992). Doing homework, arriving to class prepared and on time, and regularly attending class are all behaviors that indicate overall school engagement (Singh et al., 2002, Ingels et al., 2011a). The connection between school behaviors and math identity is not clear in previous research. This research expects to find that as engagement increases, the likelihood of stronger-social MID decreases because engagement implies that social identity is well integrated into school life and those behaviors that are normalized in the school environment. Therefore, others most likely see students with high levels of school engagement as math people.

On the other hand, the literature indicates that many students with high levels of school engagement may reject personal identification with math despite others seeing them as math persons. In an analysis of the base year of the National Educational
Longitudinal Study of 1988 (NELS:88), a nationally representative sample of eighth
grade students, Catsambis (1994) used logistic regression to discover that in the eighth
grade, girls are significantly more likely than boys to be enrolled in a high ability math
class, even though girls express significantly less interest in math. Catsambis (1994)
considered that this might be because, in general, girls display behaviors congruent with
school expectations. They are less disruptive and more diligent (Catsambis, 1994). In a
word, they are more engaged. Catsambis’s research suggests the strong possibility that
many students with high levels of school engagement are recognized as math people, but
consider their personal identities to the contrary.

2.4 Contributions to the Field

According to Martin (2009) math identity, which “encompasses a person’s self-
understandings and how they are seen by others in the context of doing
mathematics…can be used as both an indicator and an outcome for students’
mathematical experiences” (p. 328). Farrington and colleagues (2012) view academic
identity as the coalescing of student demographics, previous academic achievement, prior
knowledge, past experiences in school, and pre-existing academic mindsets. They
suggest that studies of non-cognitive factors often examine one particular factor in
isolation, making it unclear how all these factors work together. The current study looks
at the intersection of these non-cognitive factors, using MID to form counterstories to the
dominant Discourse of school mathematics achievement.

Testing for gender and racial differences in MID in a nationally representative
ninth grade sample is one method to interpret whether stereotype threat in mathematics
among females and racial minorities is more prevalent as an internal psychological threat or an external socially mediated threat. If it is found that females and racial minorities are more likely than their white male counterparts to see themselves as math persons, but believe others don’t see them as such, then it might be concluded that the threat associated with negative stereotypes remains externalized. This finding would concur with earlier findings of resilience among high achieving students who localize the threat of negative stereotypes outside of themselves and persist in mathematics to prove them wrong (McGee, 2009).

If it is found, however, that females and racial minorities, relative to their white male counterparts, are more likely to disagree that they are math persons but believe others see them that as such, we might interpret that these groups of students are more likely to disidentify with math so as to mitigate the threat of negative stereotypes. This finding may be evidence that by the ninth grade stereotype threat is sufficiently internalized.

An alternative interpretation to both of the above scenarios exists. Studying MID in the tradition of standpoint theory finds intrinsic value in students telling their own stories of mathematics participation and identification. Because math achievement is an external measure often used to cast normalizing judgments on marginalized students, researching student expressions of MID offers an alternative window into experiences with mathematics. Outcomes will be useful in predicting future participation and non-participation alike.
Chapter 3: Quantitative Methods

3.1 Introduction

Within a theoretical framework that considers “learning and a sense of identity as inseparable” (Lave & Wenger, 1991, p. 115), student expressions of math identity dissonance are valuable perspectives for deepening an understanding of math-related learning experiences. In chapter 2 numerous factors were hypothesized to influence MID expression. To test these hypotheses, this dissertation now turns to a nationally representative sample of ninth graders in the United States.

The base year of the High School Longitudinal Study of 2009 (HSLS:09) offers a dataset for measuring the significance and relative impact of variables that may influence the probability that MID is expressed. HSLS:09 is a nationally representative sample of over 21,000 ninth graders, making findings from the current study generalizable to the entire cohort of U.S. ninth graders in 2009.

As part of the student questionnaire, each of the ninth graders who participated in the study was asked whether they agree with the statements “You see yourself as a math person” and “Others see you as a math person.” Approximately 9% of the surveyed students expressed stronger-personal math identity dissonance (MID\(_p\)). MID\(_p\) is the case where individuals agree that they are math persons, but disagree that others see them as math persons. Approximately 10% of students expressed stronger-social math identity dissonance (MID\(_s\)). MID\(_s\) is the case where individuals agree that others see them as math persons, but disagree that they are math persons. MID\(_p\) and MID\(_s\) comprise the two
dependent variables of the current study. The probability of \( \text{MID}_p \) and \( \text{MID}_s \) will be measured as a function of multiple independent variables that were discussed in the previous chapter. Domain variables draw from students’ demographics, math achievement, math mindsets, and school mindsets.

The HSLS:09 base year student questionnaire began with questions about students’ gender, race, and ethnicity. Relevant questions that followed were about their history of math achievement, their attitudes and beliefs about math, and their relationship to school in general. Upon completion of the questionnaire, students took an algebra assessment.

A collection of student responses from the questionnaire and results from the algebra assessment make up the domain variables of the current study. Specific variables were selected based on a thorough review of related literature and a careful investigation of available variables from the public-use base year HSLS:09 dataset. Selected variables were uploaded to the software program SPSS for analysis. I created logistic regression models in SPSS to determine how the numerous domain variables generated in the student questionnaire and algebra assessment affect differences in the likelihood of MID expression.

3.2 Dataset

Data employed in the present study is drawn entirely from the public-use data file of the base year of the High School Longitudinal Study of 2009 (HSLS:09). Student questionnaires and algebra assessments provide the bulk of the data for the current study.
The public-use dataset also includes survey data from parents, teachers, school administrators, and school counselors. Parent response data are used in the current study to determine students’ socioeconomic status. Beyond SES and information regarding school locale, all data used in this study are a result of student responses and student participation in the algebra assessment.

HSLS:09 is the most recent study from the Secondary Longitudinal Studies Program (SLSP) sponsored by the National Center for Education Statistics (NCES). Over a period of more than 40 years, the SLSP has completed four major longitudinal studies. The base year of HSLS:09 is the beginning of the fifth study in the series. The HSLS:09 base year provides cross-sectional data for a representational sample of students who were part of the cohort of U.S. ninth graders in 2009.

HSLS:09 is the fifth study to come from SLSP over the last five decades. The SLSP began in 1972 to provide nationally representative longitudinal data about U.S. student experiences through secondary school and into adulthood (Ingels et al., 2011a). Since then, each study has built on the work of the previous studies. The studies are designed to be longitudinal, but also provide cross-sectional data to compare students at different stages. By studying the factors that affect students’ pathways through school and beyond, the SLSP provides nationally representative longitudinal samples that have been employed extensively to inform education scholarship and policy.

Beginning with the National Longitudinal Study of the High School Class of 1972 (NLS-72), the SLSP has generated data about generations of students at distinct stages in their educational and professional trajectories. Four longitudinal studies, the NLS-72,
High School and Beyond (HS&B), the National Education Longitudinal Study of 1988 (NELS:88), and the Education Longitudinal Study of 2002 (ELS:2002) have been completed. A brief overview of each study is outlined below.

NLS-72 surveyed a national sample of approximately 19,000 seniors in high school from more than one thousand public and private schools. Five follow-up surveys were conducted in 1973, 1974, 1976, 1979, and 1986. NLS-72 has established a baseline against which all subsequent secondary longitudinal studies can be measured (Ingels et al., 2011a). Annotated bibliographies report hundreds of studies conducted using NLS-72 (Maline, 1993).

Mathematics was not a focus of the NLS-72. Studies comparing the base year of NLS-72 with the base year of the next longitudinal study from SLSP, High School and Beyond (HS&B), however, showed a general decline in high school senior math achievement between 1972 and 1980 (Fetters, 1984).

HS&B was launched in 1980 and focused on two cohorts of high school students. Over 30,000 seniors were joined by a near equal number of sophomores for a total of more than 58,000 students who participated in the base year of HS&B. The cohort of seniors provided a comparative sample to the NLS-72 sample. Follow-up surveys included subsamples of both the senior and sophomore cohorts who were resurveyed in 1982, 1984, and 1986. The sophomore cohort was surveyed a final time in 1992 (Ingels et al., 2011a).
HS&B’s inclusion of sophomore students provided data on the relationships between early high school experiences and students’ subsequent educational experiences and career choices. According to NCES, it was the first time that “national data were available that showed students’ academic growth over time and how family, community, school, and classroom factors were associated with student learning” (Ingels et al., 2011a). HS&B provided an empirical base to inform research and educational reform policy throughout the 1980s (Ingels et al., 2011a).

Marsh (1991) used HS&B to measure the importance of academic “self-concept” and school aspirations. He found that students from higher-ability schools have lower academic self-concepts. He concluded that this was likely because in-group comparisons lowered students’ self-beliefs relative to high performing peers (Marsh, 1991).

Following HS&B, NELS:88 began gathering data about the eighth grade class of 1988. Data compiled about eighth graders served as a baseline for investigating students’ high school experiences. In addition to filling out a questionnaire, student participants in NELS:88 base year completed assessments in reading, mathematics, science, and social studies. A first follow-up resurveyed students in their tenth grade year. A second follow-up surveyed students in the spring of 1992, when most sample members were in their final semester of high school. There were two post-high school follow-ups. The first was in 1994 when participants were two years beyond intended high school graduation. The last was in 2000, when many sample members had completed their postsecondary education. NELS:88 produced three nationally representative cohorts of students in the eighth grade, tenth grade, and twelfth grade (Ingels et al., 2011a). These data continue to
inform research and policy regarding educational attainment and the many factors that are considered to influence it.

Salient findings from the NELS:88 study have been reported in hundreds of publications. In regards to the current dissertation, Catsambis (1994) employed NELS:88 data to trace the development of gender differences in attitudes towards mathematics among White, Black, and Latinas/os, and among males and females. She found that White females have the greatest mathematics learning advantage, but express some of the lowest attitudes towards math.

The fourth in the series of SLSP studies, ELS:2002 gathered information about a nationally representative sample of students beginning in the tenth grade. ELS:2002 included a math assessment of students in their tenth and twelfth grade years. The study investigated factors that influence academic achievement and factors that affect students’ leaving the educational system. There was a special focus on the transition from high school to post-secondary education and the influence of mathematics achievement in that transition (Ingels et al., 2011a).

The SLSP has provided data for thousands of research publications and hundreds of dissertations. SLSP findings continue to be used to inform policy at the local and national level. HSLS:09 is the most recent study in the series. It varies from previous secondary longitudinal studies in a number of important ways. Unlike past studies, the base year for HSLS:09 was a cross-sectional study of ninth grade students. The student questionnaire was for the first time computer-administered in a school setting, which allowed for much cleaner data collection. Parent, teacher, administrator, and school counselor questionnaires were also administered via the web. The HSLS:09, which
included questions about mathematics identity, had an enhanced emphasis on science, technology, engineering, and technology (STEM) trajectories. The HSLS:09 base year survey is also the first of the studies to include an assessment focused exclusively on algebraic reasoning (Ingels et al., 2011a).

The student survey was conducted during the regular school day (Ingels et al., 2011a). It took approximately 90 minutes to administer. 98 percent of students were surveyed during in-school sessions. Two percent participated in out-of-school sessions. The survey consisted of 15 minutes for setup and instructions, 35 minutes to complete the student questionnaire, and 40 minutes for the two-part, 40-question adaptive algebraic reasoning assessment. Face to face instructions were given during the set-up time, but the questionnaire and the algebra assessment were administered via a computer. Students who completed the survey outside of school did not take the algebra assessment (Ingels et al., 2011a).

HSLS:09 was the first time that computers administered both the questionnaire and the algebra assessment (Ingels et al., 2011a). It is also the first of the studies to specifically investigate students’ mathematics identity. Additionally, the study design produced scales of math self-efficacy, math utility, math interest, school belonging, and school engagement. These composite scales were based on two or more manifest variables. Possible responses ranged from strongly disagree to strongly agree on a four point Likert-scale. Math achievement information was collected by asking students to provide information regarding their current math course and math teacher and to report their previous year’s math course, including their final grade in that course. Its
standardized 40-question math assessment measured proficiency in what the survey
design considers the “major domains of algebra and the key processes of algebra” (Ingels
et al., 2011, A-4). Taken together, these data provide wide-ranging descriptions of
student experiences in school mathematics.

3.3 Analytic Samples

The HSLS:09 base year study employed multi-stage cluster sampling to arrive at a
nationally representative sample of over 25,000 eligible ninth grade students in more than
900 schools. Across the United States, more than 1,800 public, private, parochial and
charter schools were randomly selected for the study. Eligible schools were those that
provided instruction in ninth and eleventh grade. Of the selected schools, 944 opted to
participate in the study. These included schools from all 50 states and the District of
Columbia (Ingels et al., 2011a).

After administrators from the selected schools elected to participate in the study,
there was a second randomized sampling of students from each school roster. On
average, 27 ninth grade students from each school were randomly selected to participate
in the study. This resulted in an initial sample size of 25,206 students. From this group
of students, 548 were determined questionnaire-incapable due to language barriers or
severe disabilities. From the remaining questionnaire capable students, another 3,214
non-respondents were not available to participate or opted out of the study. The 21,444
remaining students participated in the base year questionnaire. Table 3.1, adapted from
*HSLS:09 Base-Year Data File Documentation* (Ingels, Dalton, Holder, Lauff & Burns,
2011) represents response rates based on student characteristics (sex and race/ethnicity).
Table 3.1

*HSLS:09 Student Response Rates by Student Characteristic*

<table>
<thead>
<tr>
<th>Sample member characteristic</th>
<th>Eligible students</th>
<th>Responders</th>
<th>Response Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>25,206</td>
<td>21,444</td>
<td>85.1</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>12,885</td>
<td>10,887</td>
<td>85.0</td>
</tr>
<tr>
<td>Female</td>
<td>12,321</td>
<td>10,557</td>
<td>85.7</td>
</tr>
<tr>
<td>Race/ethnicity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>American</td>
<td>249</td>
<td>223</td>
<td>89.6</td>
</tr>
<tr>
<td>Indian/Alaska Native</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asian/Pacific Islander</td>
<td>2,576</td>
<td>2,144</td>
<td>83.2</td>
</tr>
<tr>
<td>Black or African American</td>
<td>3,115</td>
<td>2,684</td>
<td>86.2</td>
</tr>
<tr>
<td>Hispanic</td>
<td>3,958</td>
<td>3,516</td>
<td>88.8</td>
</tr>
<tr>
<td>White</td>
<td>14,702</td>
<td>12,630</td>
<td>85.9</td>
</tr>
<tr>
<td>Other Race, more than one race, missing</td>
<td>606</td>
<td>247</td>
<td>40.8</td>
</tr>
</tbody>
</table>

From the 21,444 students who completed the questionnaire, 285 participants did not respond to the questions about how much they agree or disagree with the statements, “You see yourself as a math person” and “others see you as a math person.” This reduced the analytic sample of students who expressed either MID or not-MID to 21,159.

Further constraints to the analytic sample included in the analytic models will be addressed in the discussion of the analytic strategy later in this chapter.

HSLS:09 is designed so that students are the fundamental unit of analysis. In addition to the algebra assessment and the student questionnaire, the students’ parents, administrators, guidance counselors, math teachers, and science teachers were surveyed.
Parent responses to education, occupation, and family income questions, the variables comprising socioeconomic status (SES), are included in the current study.

The HSLS:09 includes four follow up years. The first follow up occurred in January of 2012, when the original ninth graders were scheduled to be in the middle of their eleventh grade year. In addition to a survey, students took a second mathematics assessment so that the study could measure mathematical growth. Subsequent data collections are scheduled for 2016, two years after the expected high school graduation, and again in 2021 to learn about participants’ experiences in adulthood. Follow-up surveys are not included in the current study but will provide an analytic sample for future MID studies.

3.4 Measures

Each of the variables included in the study was generated using the public-use HSLS:09 base year dataset. The current study includes two separate dichotomous dependent variables, which will be discussed in section 3.4.1. Four domains of independent variables grouped by student demographics, math achievement, math mindsets, and school mindsets are included in the analytic models of this study. The primary NCES researchers created several composite variables included in this analysis. Each of these will be discussed in section 3.4.2. SPSS statistics software was used to recode variables that needed additional preparation to be included in the analytic plan. The recoding process will be discussed when applicable.
3.4.1 Dependent Variables. For the majority of ninth grade students who participated in the base year of the HSLS:09, there was strong agreement in their responses to two questions that are used as a measure of math identity. “You see yourself as a math person” and “Others see you as a math person” operationalize the construct of mathematics identity (α = .84) (Ingels et al., 2011a). The dependent variables of the current study, MID$_p$ and MID$_s$, are defined by the cases when these two aspects of an individual’s math identity are in disagreement.

Stronger-personal (MID$_p$) and stronger-social (MID$_s$) math identity are used to disaggregate the two distinct expressions of MID. MID$_p$ is the dissonance that occurs when an individual’s personal-math identity is positive and their social-math identity is negative. MID$_s$ is expressed when an individual’s personal-math identity is negative and their social-math identity is positive. The difference in students’ responses from two questionnaire items: How much do you agree or disagree with the following statements: “You see yourself as a math person” and “Others see you as a math person.” operationalize the dependent variables of this study.

Responses to each of the two questions above ranged over “strongly agree (1),” “agree (2),” “disagree (3),” and “strongly disagree (4).” Before calculating the difference, the 4-point Likert-scale was collapsed to a 2-point scale so that only different valences (agreement/disagreement) would be preserved. Strongly agree (1) and agree (2) were coded to a single number, 1. Disagree (3) and strongly disagree (4) were coded to a single number, 2. Calculating the difference in agreement to “You see yourself…” and “Others see you…” resulted in integer values between -1 and 1. -1 corresponds to MID$_p$. 
students who either agree or strongly agree that they see themselves as a math person, but disagree or strongly disagree that others see them as a math person. 1 corresponds to MID, students who disagree or strongly disagree that they see themselves as a math person, but agree or strongly agree that others view them as a math person. 0 implies simply that the responses to the two math identity questions are the same. It does not convey whether the student positively or negatively identifies with mathematics. From the 21,444 student questionnaires, 21,159 students replied to both questions. The table below shows the frequency of MID expression in the representative sample of ninth grade students.

Table 3.2

<table>
<thead>
<tr>
<th>MID_p</th>
<th>MID_s</th>
<th>No MID</th>
<th>Missing</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,953</td>
<td>2,199</td>
<td>17,007</td>
<td>285</td>
<td>21,444</td>
</tr>
<tr>
<td>(9.1)</td>
<td>(10.3)</td>
<td>(79.3)</td>
<td>(1.3)</td>
<td>(100)</td>
</tr>
</tbody>
</table>

3.4.2 Independent Variables. A total of 17 manifest and latent independent variables are used in this study. Nominal and ordinal variables were taken directly from the publicly available HSLS:09 base year dataset. Additional latent variables created by the primary researchers of HSLS:09 are used. In several cases it is necessary to recode the data so that it can be used in the models. Each case of recoding is discussed in subsequent sections in this chapter.

The independent variables in this study range over four domains. The first domain, student demographics, captures information about student gender, race, urbanicity, and socioeconomic status. The second domain of variables measures math
achievement based on student performance on the HSLS:09 algebra assessment, the final grade in eighth grade math class, and the most advanced math course taken in the eighth grade. In response to research regarding non-cognitive factors that affect educational outcomes, the third and fourth domains measure student beliefs, attitudes, and dispositions, which this dissertation refers to as mindsets. Domain three employs several standardized scales of math mindsets that were constructed by researchers in the design of HSLS:09. These include scales of math utility, math self-efficacy, and interest in math. Domain four measures broader school mindsets, which include scales of school belonging and school engagement.

3.4.2.1 Student demographics domain variables. Domain variables that describe student demographics measure how gender, race, and SES influence the probability of MID expression. The first demographic variable considered in this study is gender. The composite variable for gender in the HSLS:09 base year public use dataset is X1SEX. As discussed earlier, gender is a particularly salient variable. Catsambis (1994) finds that even when achievement, ability group placement, and social background are taken into account, female students are less likely than males to look forward to math class, to believe that math will be useful to their future, and to participate in relevant extracurricular activities.

In the questionnaire, students were asked, “What is your sex?” There were two possible response categories for this question, “Male” or “Female.” If sex data were inconsistent across the student questionnaire, parent questionnaire, and/or school-
provided sampling roster, X1SEX was coded based on a manual review of the sample member's first name. Table 3.3 shows bivariate frequencies for MID by gender.

Table 3.3

<table>
<thead>
<tr>
<th></th>
<th>MID&lt;sub&gt;s&lt;/sub&gt;</th>
<th>MID&lt;sub&gt;p&lt;/sub&gt;</th>
<th>no-MID</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>1,164</td>
<td>956</td>
<td>8582</td>
<td>10,702</td>
</tr>
<tr>
<td></td>
<td>(10.9)</td>
<td>(8.9)</td>
<td>(80.2)</td>
<td>(100)</td>
</tr>
<tr>
<td>Female</td>
<td>789</td>
<td>1,243</td>
<td>8,425</td>
<td>10,457</td>
</tr>
<tr>
<td></td>
<td>(7.5)</td>
<td>(11.9)</td>
<td>(80.6)</td>
<td>(49.4)</td>
</tr>
<tr>
<td>Total</td>
<td>1,953</td>
<td>2199</td>
<td>17,007</td>
<td>21,159</td>
</tr>
<tr>
<td></td>
<td>(9.2)</td>
<td>(10.4)</td>
<td>(80.4)</td>
<td>(100)</td>
</tr>
</tbody>
</table>

From the table above we see that boys compromise 60% of the population of students who exhibit stronger-personal MID. This trend is reversed for stronger-social MID. Females compromise 57% of all the students expressing MID.<sup>s</sup>

Another demographic variable that is prominent in the related literature is race. X1RACE is the composite variable that describes race/ethnicity characteristics for the HSLS:09 student sample. To elicit race in the HSLS:09 student questionnaire, all students were asked first whether they are Hispanic or Latino/Latina. If students replied affirmatively, they were prompted to identity a Latin American country or geographic region that described them. For all students, regardless of their response to being Hispanic, they were asked, “Which of the following describe your race? You may choose more than one. (Check all that apply.)” Response categories included: White; Black or African American; Asian; Native Hawaiian or other Pacific Islander; and
American Indian or Alaska Native. From these questions, the variable X1RACE was formed, which assigns each member of the sample a racial category. Employing X1RACE, the current study controls for race over the following racial categories: White, Black, Hispanic, Asian, and Other Race. “Other Race” includes Native American, Alaskan natives, Pacific Islanders, and students who identify as more than one race.

Table 3.4

<table>
<thead>
<tr>
<th>Race/Ethnicity</th>
<th>MID&lt;sub&gt;1&lt;/sub&gt;</th>
<th>MID&lt;sub&gt;2&lt;/sub&gt;</th>
<th>no-MID</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>198</td>
<td>237</td>
<td>1,783</td>
<td>2,218</td>
</tr>
<tr>
<td></td>
<td>(8.9)</td>
<td>(10.7)</td>
<td>(80.4)</td>
<td>(100)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>374</td>
<td>365</td>
<td>2,776</td>
<td>3,515</td>
</tr>
<tr>
<td></td>
<td>(10.6)</td>
<td>(10.4)</td>
<td>(79.0)</td>
<td>(100)</td>
</tr>
<tr>
<td>Asian</td>
<td>125</td>
<td>224</td>
<td>1,323</td>
<td>1,672</td>
</tr>
<tr>
<td></td>
<td>(7.4)</td>
<td>(13.4)</td>
<td>(79.0)</td>
<td>(100)</td>
</tr>
<tr>
<td>Other Race</td>
<td>191</td>
<td>252</td>
<td>1,742</td>
<td>2,185</td>
</tr>
<tr>
<td></td>
<td>(8.7)</td>
<td>(11.5)</td>
<td>(79.7)</td>
<td>(100)</td>
</tr>
<tr>
<td>White</td>
<td>1,065</td>
<td>1,121</td>
<td>9,668</td>
<td>11,854</td>
</tr>
<tr>
<td></td>
<td>(9.0)</td>
<td>(9.5)</td>
<td>(81.6)</td>
<td>(100)</td>
</tr>
</tbody>
</table>

Socioeconomic status (SES) is computed based on family income (X1FAMINCOME), parent education (X1PAR1EDU and X1PAR2EDU), and parent occupation (X1PAR1OCC2 and X1PAR2OCC2). The current study employed X1SES, a composite index, constructed as a function of five component variables that were generated in the parent/guardian questionnaire. These five variables include:

- The highest education among parents/guardians in the two-parent family of a responding student, or the education of the sole parent/guardian (X1PAR1EDU).
The education level of the other parent/guardian in the two-parent family (X1PAR2EDU).

The highest occupation prestige score among parents/guardians in the two-parent family of a responding student, or the prestige score of the sole parent/guardian (X1PAR1OCC2).

The occupation prestige score of the other parent/guardian in the two-parent family (X1PAR2OCC2).

Family income (X1FAMINCOME) (Ingels et al., 2011a).

Farrington and colleagues (2012) suggest that student SES is “very likely to mediate the relationships among the classroom context, the student’s further development or enactment of noncognitive skills, behaviors, attitudes and strategies in that classroom; and academic performance” (p. 12). Table 3.5 shows MID frequencies by SES quintiles:

<table>
<thead>
<tr>
<th>SES Quintile</th>
<th>MID₁</th>
<th>MID₂</th>
<th>no-MID</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>First quintile</td>
<td>364</td>
<td>329</td>
<td>2,666</td>
<td>3,359</td>
</tr>
<tr>
<td>(lowest)</td>
<td>(10.8)</td>
<td>(9.8)</td>
<td>(79.4)</td>
<td>(100)</td>
</tr>
<tr>
<td>Second quintile</td>
<td>356</td>
<td>366</td>
<td>2,928</td>
<td>3,650</td>
</tr>
<tr>
<td>(9.8)</td>
<td>(10.0)</td>
<td>(80.2)</td>
<td>(100)</td>
<td></td>
</tr>
<tr>
<td>Third quintile</td>
<td>430</td>
<td>398</td>
<td>3,355</td>
<td>4,183</td>
</tr>
<tr>
<td>(10.3)</td>
<td>(9.5)</td>
<td>(80.2)</td>
<td>(100)</td>
<td></td>
</tr>
<tr>
<td>Fourth quintile</td>
<td>422</td>
<td>490</td>
<td>3,590</td>
<td>4,502</td>
</tr>
<tr>
<td>(9.4)</td>
<td>(10.9)</td>
<td>(79.7)</td>
<td>(100)</td>
<td></td>
</tr>
<tr>
<td>Fifth quintile</td>
<td>381</td>
<td>616</td>
<td>4,468</td>
<td>5,465</td>
</tr>
<tr>
<td>(highest)</td>
<td>(7.0)</td>
<td>(11.3)</td>
<td>(81.8)</td>
<td>(100)</td>
</tr>
</tbody>
</table>
Urbanicity is included in the model as a factor that differentially affects SES relative to social position. Though SES is a factor anywhere, low SES is arguably different in the city than in rural and suburban areas. In the case of schools, past research has shown great disparities in funding between urban public schools and their suburban counterparts. In *Savage Inequalities*, Kozol (1991) illustrates grave conditions in public schools in densely populated, urban locales. The current study controls for urban and not-urban in the models, but does not differentiate between the four distinct school locales (rural, town, suburban and urban) that are identified in the HSLS:09.

Domain I variables include X1SEX, X1RACE, X1SES, and, urbanicity. These demographics allow for a more complete picture of those students exhibiting MID. Social anthropologist Dorothy Holland writes:

Clearly a person’s social position—defined by gender, race, class, and any other social division that is structurally significant—potentially affects one’s perspective on cultural institutions and the ardor of one’s subscription to the values and interpretations that are promoted in rituals and other socially produced cultural forms. (Holland, 1997, p. 168)

The current study will be crucial to see how social position affects student perspectives on how they see themselves and believe others see them as math persons.

**3.4.2.2 Math achievement domain variables.** Domain II variables include the standardized theta score of the algebra assessment included in the HSLS:09 base year survey (X1TXMTSCOR), reported final grade from eighth grade math course (S1M8GRADE), and categorical data regarding students’ most advanced eighth grade math course.
As part of HSLS:09, students participated in a two-stage 40 minute computer adaptive assessment of algebraic proficiency that measured across five domains and four key processes. Of the 21,444 students who participated in the questionnaire, 20,781 also completed the algebra assessment. The five domains of algebra include what the study calls: the language of algebra; proportional relationships and change; linear equations, inequalities, and functions; and systems of equations. The four key processes include: demonstrating algebraic skills; using representations of algebraic ideas; performing algebraic reasoning; and solving algebraic problems (Ingels et al., 2011a).

The test was adaptive, based on two stages. All students took the same 15-question router in the first stage. Based on these results, each student was assigned a low, moderate, or high level of difficulty in the second stage of test. The second stage included 25 problems. The moderate and high-level test had 12 of the 25 questions in common. The moderate and low-level test had 5 of the 25 questions in common (Ingels et al., 2011a). This resulted in a consistent measure of math proficiency that can be used to analyze the impact of performance in the expression of MID.

Table 3.6, adopted from the report *High School Longitudinal Study of 2009 (HSLS:09): A First Look at Fall 2009 Ninth-Graders* (Ingels et al., 2011b), shows the percentage of ninth graders proficient in specific algebra knowledge and skills measured on the assessment, by student, and family characteristics.
Table 3.6

*Mathematics Proficiency: Percentage of Ninth-Graders Proficient in Specific Algebra Knowledge and Skills, by Student, and Family: 2009*

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Level</th>
<th>1-Algebraic expressions</th>
<th>2-Multiplicative and proportional thinking</th>
<th>3-Algebraic equivalence</th>
<th>4-systems of equations</th>
<th>5-linear functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>85.7</td>
<td>59.1</td>
<td>41.3</td>
<td>18.3</td>
<td>9.2</td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>84.5</td>
<td>58.9</td>
<td>41.6</td>
<td>18.7</td>
<td>9.4</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>86.8</td>
<td>59.4</td>
<td>41.0</td>
<td>17.9</td>
<td>8.9</td>
<td></td>
</tr>
<tr>
<td>Race/Ethnicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White, non-Hispanic</td>
<td>89.7</td>
<td>65.7</td>
<td>47.5</td>
<td>21.3</td>
<td>10.2</td>
<td></td>
</tr>
<tr>
<td>Black, non-Hispanic</td>
<td>74.4</td>
<td>41.3</td>
<td>25.5</td>
<td>10.4</td>
<td>6.3</td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asian, non-Hispanic</td>
<td>82.4</td>
<td>52.1</td>
<td>33.7</td>
<td>13.6</td>
<td>7.2</td>
<td></td>
</tr>
<tr>
<td>All other races</td>
<td>83.9</td>
<td>56.4</td>
<td>38.4</td>
<td>16.1</td>
<td>8.4</td>
<td></td>
</tr>
</tbody>
</table>

Socioeconomic Status

<table>
<thead>
<tr>
<th></th>
<th>1-Algebraic expressions</th>
<th>2-Multiplicative and proportional thinking</th>
<th>3-Algebraic equivalence</th>
<th>4-systems of equations</th>
<th>5-linear functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowest fifth</td>
<td>74.0</td>
<td>41.3</td>
<td>24.3</td>
<td>9.4</td>
<td>6.0</td>
</tr>
<tr>
<td>Middle three-fifths</td>
<td>86.0</td>
<td>57.3</td>
<td>38.9</td>
<td>16.0</td>
<td>8.1</td>
</tr>
<tr>
<td>Highest Fifth</td>
<td>95.9</td>
<td>80.4</td>
<td>65.0</td>
<td>33.7</td>
<td>15.4</td>
</tr>
</tbody>
</table>

(Ingels et al., 2011b)

The current study includes the math standardized T score. This score is based on statistical estimates of the total number of correct answers. It is rescaled to a mean of 50 and standard deviation of 10. According to Ingels and colleagues (2011a), this score provides an achievement estimate relative to the entire population of ninth graders in 2009.
In addition to their performance on the HSLS:09 algebra assessment, students were asked to report their final grade from their most advanced eighth grade math course. Because the survey was administered in the fall of their ninth grade year, this grade was the last summative evaluation that students received regarding their mathematical performance and progress before taking the survey. In the current study, this grade was treated as a continuous variable. “Below a D” was coded a 1, D was coded 2, C was coded 3, B was coded 4, and A was coded 5. Missing grades were not included in the study.

Finally, by the time students reach high school, many are tracked into specific lower or higher level math courses. Numerous studies show how tracking in the transition from middle to high school determines future educational outcomes. The student’s current math course is included in this study with the understanding that there is a regular hierarchy in the progression of school mathematics courses of which students are aware. In the current study, eighth grade math and pre-algebra were combined into a single nominal variable and measured relative to “Algebra”, “advanced math” (geometry, Algebra II, trigonometry, and pre-calculus), and “other math” courses. “Other math” included those courses not obviously positioned in the progression of traditional school math.

As students set out to learn and practice mathematics, they are consistently met with summative measures of their math abilities in the form of test scores, class grades, and course placement. Acknowledging that there is likely a reciprocal relationship between how students identify with mathematics and how they perform in school
mathematics Discourse (Marsh, Walker, & Debus, 1991; Martin, 2009), supports the need to analyze the effect of these available measures of mathematical achievement on MID.

3.4.2.3 Math mindsets domain variables. Domain III variables measure changes in the probability of MID expression as a function of math mindsets. These variables focus on student attitudes towards their current math course. Three scales of math mindsets created in the HSLS:09 study design are included in the current study. These include scales of math utility, math self-efficacy, and math interest. Each of these variables is a composite variable created from student questionnaire items. Each variable was standardized to a mean of 0 and a standard deviation of 1.

Students’ math-utility scale ($\alpha = 0.78$) is a scale of student perceptions of the usefulness of mathematics (Ingels et al., 2011a). The inputs to this scale were responses to the questions: “How much do you agree or disagree with the following statements about the usefulness of your math course?”

- What students learn in this course is useful for everyday life (S1MUSELIFE).
- What students learn in this course will be useful for college (S1MUSECLG).
- What students learn in this course will be useful for a future career (S1MUSEJOB).
Only students who provided a full set of responses were assigned a scale value. If the student indicated that he or she was not taking a fall math class, this variable is coded as a legitimate skip and not included in the current study.

Students’ math self-efficacy is a scale ($\alpha = 0.90$) that was created by responses to the following: “How much do you agree or disagree with the following statements about your [fall 2009 math] course?”

- You are confident that you can do an excellent job on tests in this course (S1MTESTS)
- You are certain that you can understand the most difficult material presented in the textbook used in this course (S1MTEXTBOOK).
- You are certain that you can master the skills being taught in this course (S1MSKILLS).
- You are confident that you can do an excellent job on assignments in this course (S1MASSEXCL).

Only respondents who provided a full set of responses were assigned a scale value. If the student indicated that he or she was not taking a fall math class, this variable was coded as a legitimate skip and not included in the current study (Ingels et al., 2011a).

Math interest is a scale ($\alpha = 0.75$) of student interest in their fall 2009 math course. This scale was created from responses to the following questions: “How much do you agree or disagree with the following statements about your [fall 2009 math] course?”

- You are enjoying this class very much (S1MENJOYING).
• You think this class is a waste of your time (S1MWASTE).

• You think this class is boring (S1MBORING).

Other questions factored into this scale include: “Not including lunch or study periods, what is your favorite school subject?” (S1FAVSUBJ) and “Not including lunch or study periods, what is your least favorite school subject?” (S1LEASTSUBJ). Lastly, if students checked “you really enjoy math” (S1MENJOYS), when instructed to check all statements that apply in an earlier section of the questionnaire, the response was factored in as well. If the student indicated that he or she was not taking a fall math class, this variable was coded as a legitimate skip and not included in the current study (Ingels et al., 2011a).

3.4.2.4 School mindset domain variables. Domain IV variables are measures of school mindsets. The variables included in this study are scales of school belonging and school engagement. Each variable was standardized to a mean of 0 and a standard deviation of 1.

The scale of school belonging (α = 0.72) is a composite variable formed from responses to the questions: “How much do you agree or disagree with the following statements about your [fall 2009 math] course?”

• You feel safe at this school (S1SAFE)
• You feel proud being part of this school (S1PROUD)
• There are always teachers or other adults in this school that you can talk to if you have a problem (S1TALKPROB)
• School is often a waste of time (S1SCHWASTE)
• Getting good grades in school is important to you (S1GOODGRADES)

Only students who provided a full set of responses to all questions included in the school belonging scale were assigned a scale value (Ingels et al., 2011a).

The scale of school engagement ($\alpha = 0.67$) is a composite variable formed from responses to the questions: “How often do you...”

• Go to class without your homework done (S1NOHWDN)
• Go to class without pencil or paper (S1NOPAPER)
• Go to class without books (S1NOBOOKS)
• Go to class late (S1LATE)

Possible responses ranged over 1) never, 2) rarely, 3) sometimes, 4) often. Only students who provided a full set of responses to all the questions included in the school engagement scale were assigned a scale value (Ingels et al., 2011a).

3.5 Analytical Strategy

All data are uploaded in SPSS from the public-use file of the base year of HSLS:09. As specified in the previous section, some data are recoded for use in the current study. Two dependent variables are measured in this study. $\text{MID}_p$ is the case where individuals agree that they are math persons but disagree that others see them as math persons. $\text{MID}_s$ is the case where individuals disagree that they are math persons but agree others see them as math persons. The current study will measure differences in the
probability that each of these dependent variables will be expressed. The results of the analysis are presented as odds ratios of the independent variables. Odds ratios are the change in the odds of MID expression for every unit change in the predictor variable. Predictor variables that are nominal are compared to a dummy variable.

In both types of MID, a student either displays this characteristic or does not. Logistic regression models are used because of the dichotomous nature of the dependent variables. For each set of models, MIDᵣ or MIDₛ are compared to the dummy case of not-MIDᵣ or not-MIDₛ. The significance and relative impact of independent student-level variables are measured over four domains: demographics, math achievement, math mindset, and school mindsets. Predictors include nominal, ordinal, and interval ratio variables. Analyses are conducted hierarchically to control for an increasing number of predictor variables.

Four domains of independent variables were selected based on unresolved questions that arose through a review of the literature. Below is an overview of how these domain variables factor into models I through IV, which treat stronger-personal math identity as the dependent variable. The analysis is repeated in models V through VIII for stronger-social math identity dissonance.

In Model I, the key independent variables are gender, race, and socioeconomic status (SES). This model will assess the degree to which certain demographic characteristics are significant to predict the occurrence of stronger-personal and stronger-social MID. Throughout the related literature, the first demographic variable, gender, is critical to mathematics identity. In addition to treating it as an independent variable in
models I through VIII that compare all students, gender comparisons will be made by looking at females and males separately in models IX through XXIV.

In the analysis, male will be coded as the dummy when controlling for gender, while White will be the reference variable when controlling for race. In regards to gender, there were only two possible response categories in the survey that students completed, male and female. This required that students adhere to gender-normative constructs that neglect the existence of intersex and transgendered youth. Meanwhile, racial categories first asked students to distinguish whether they are Hispanic or Latino/a, after which students were prompted as to their racial background and instructed to assign as many racial distinctions as they identified with, which included: White, Black or African American, Asian, Native Hawaiian or other Pacific Islander, and American Indian or Alaska Native. Because of the relatively low response numbers of Native Hawaiian, other Pacific Islander, American Indian or Alaska Native included in the study, these racial categories will be combined and labeled “other race.” Also included in “other race” are students who indicated more than one race. Additionally, Hispanic students of all races will be characterized as Hispanic in the current study.

In addition to race and gender, school locale (urbanicity) and socioeconomic status (SES) will be considered. Although primary survey data differentiated between four types of school locales, town, rural, suburban, and urban, the urbanicity measure used in this analysis will treat urbanicity dichotomously, capturing only whether a student lives in a city or not. For the purposes of this study, “city” was coded to be the reference variable. Socioeconomic status is a continuous variable that was discussed in the previous
section. It is a latent variable made up of parent education, occupation, and family income.

Taken together these demographic variables begin to generate a portrait of fundamental student characteristics. Although student responses were structured by the survey questions, these characteristics begin to shape our understanding of the relationship of MID to students’ personal identities in a larger sociological context.

Model II measures whether math achievement and measured math proficiency have an impact on MID. It is theorized that there is a reciprocal relationship between identity and achievement (Marsh et al., 1991, Martin, 2009). The current study will measure MID differences based on math proficiency on the algebra assessment, prior math grades, and ability tracks.

Math achievement variables capture some of the ways that students are known by others in the context of doing math. A standardized score on an algebra assessment is used as an objective measure of student performance within grade-level appropriate algebra domains. Final math grade in eighth grade was measured on a scale from a failing grade, F, to an A, coded with the integers 1 through 5. Grades are included as an indicator of how students were judged in their previous year of math class. Eighth grade math course is a measure of the last math course completed by the student, which indicates ability tracking. The reference variable to measure eighth grade math course is eighth grade math/pre-algebra. Additional ability tracks include Algebra, “advanced math,” and “other math”. Advanced math includes any course beyond Algebra. Other math includes any course that is not included in a traditional math sequence.
Model III will focus on student math mindsets. Past research has compared math self-concept to math self-efficacy and utility (Pajares & Miller, 1994). Sample member interest in current math course is also considered in the theoretical framework that endorses Dewey’s conflating of interest and personal identity in a theory of learning. Model III will measure the degree to which MID varies with these variables concerning math mindsets. This is particularly useful because although issues of identity are malleable (Holland et al., 1988; Oyserman, 2009), they are multi-faceted and difficult to change directly. Mindsets, however, are much easier to address head-on, with the idea that coherent and positive math identities may be positively affected by mindset interventions (Farrington et al., 2012).

Model IV will measure the impact of school mindsets on MID. Within a communities of practice framework, engagement and belonging are crucial to consider. Additionally, research from academic mindsets suggests that measures of study habits and persistence are relevant to the formation of academic identities (Dweck et al., 2011; Farrington et al., 2012).

In the previous chapter, hypotheses were made regarding each of these domains. To test these hypotheses the likelihood of MID expression will be measured using logistic regression analysis. Hypotheses include:

- Stronger-personal MID expression is more likely in male students
- Stronger-social MID expression is more likely in female students
- Black and Hispanic students are more likely to express stronger-personal MID than their White counterparts
Asian students are more likely to express stronger-social MID than their White counterparts

The likelihood of either form of MID decreases for higher SES students

Higher levels of math achievement decrease the likelihood of stronger-personal MID but increase the likelihood of stronger-social MID

Interest in mathematics will increase the likelihood of stronger-personal MID

Higher self-efficacy will decrease the likelihood of both stronger-personal and stronger-social MID

Higher school belonging will decrease the likelihood of stronger-personal and stronger-social MID

Higher school engagement will increase the likelihood of stronger-social MID

Results from the current study will be compared to the related literature and considered in the context of the theoretical framework.

Logistic regression analyses calculate changes in the probability that MID is expressed as a function of 17 independent variables that are grouped in 4 domains. Because of the importance of gender in related literature, this study will also make intra-group comparisons by generating separate models for females and males. These models will be measured over the same groups of domain variables.

Logistic regression models are created for the two types of MID. Eight models calculate odds ratios of MID for the entire sample of ninth grade students. These analyses are repeated for females and males separately, resulting in 16 additional models.
A total of 24 models are used to begin to form a portrait of students experiencing stronger-personal and stronger-social math identity dissonance.

In summary, logistic regression analysis determines the significance and relative impact of 17 predictor variables on the probability of math identity dissonance. Both MID$_p$ and MID$_s$ are compared to the rest of the population in separate logistic regression models. Four groups of domain variables are included in the analysis to measure the odds ratio of MID expression based on demographic factors, math achievement, math mindsets, and school mindsets. Because gender shows up in the research and preliminary explorations of the data as a significant predictor of MID, each model will be looked at across genders and separately for females and males. 24 logistic regression models will be discussed as a result of this analysis.
Chapter 4: Results

4.1 Introduction

This research uses logistic regression analysis to predict changes in the likelihood of MID expression based on a number of categorical and continuous independent variables grouped in four separate domains. Stronger-personal math identity (MID\textsubscript{p}) and stronger-social math identity dissonance (MID\textsubscript{s}) were the dependent variables of separate sets of logistic regression models. In each of the models, the dichotomous dependent variables MID\textsubscript{p} or MID\textsubscript{s} were compared to the dummy case of not-MID\textsubscript{p} or not-MID\textsubscript{s}. The domains of predictor variables include student demographics, math achievement, math mindsets, and school mindsets. Within each of these domains, two or more independent variables are included.

The base year of HSLS:09 provided the data for the analysis. Tests were run on SPSS and used to generate 24 separate models. Change in the probability of MID expression was treated as a function of 17 variables grouped in 4 different domains. The odds ratio of each of the independent variables was calculated using logistic regression analysis.

Models I through IV measure the independent variables’ affect on the probability of MID\textsubscript{p} expression for the entire sample. Models V through VIII measure the independent variables’ affect on the probability of MID\textsubscript{s} expression among the entire sample. Models IX through XII measure the independent variables’ affect on the probability of MID\textsubscript{p} expression in the subsample of female students. Models XIII through XVI measure the independent variables affect on the probability of MID\textsubscript{s} expression in the subsample of female students. Models XVII through XX measure the
independent variables impact on the probability of MID_p expression in the subsample of male students. Models XXI through XXIV measure the independent variables impact on the probability of MID_s expression in the subsample of male students.

In Models I through XXIV the calculated regression coefficients are log-odds. Taking the inverse of the log-odds gives the odds ratio for each independent variable in the study. For every unit increase in the independent variable, MID expression (MID_p or MID_s) changes by a factor of the odds ratio. Multiple models control for an increasing number of domain variables.\(^6\)

### 4.2 Analysis of Stronger-Personal Math Identity Dissonance (MID_p) Among All Students

Models I through IV are summarized in Table 1. These models predict the odds ratios of MID_p expression based on student-level independent variables. The analysis in Models I through IV was conducted on the entire population. Due to large numbers of legitimate skip items in math mindset domain variables, the analytic sample size is 16,904 students. This was due to the survey design which bypassed these questions for students not enrolled in a fall math course at the time of the survey.

Models I through Model IV compare students who express stronger-personal math identity dissonance to students who do not. The logistic regression analysis was conducted four times. Each subsequent model increased in complexity to control for a greater number of possible predictors. For the following analysis, n=16,904. All

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\(^6\) Logistic regression is a common analytic model used throughout the social sciences to examine the impact of predictor variables on dichotomous dependent variables. For more information on logistic regression analysis consult Agresti’s (2002) *Categorical Data Analysis* or Hilbe’s (2009) *Logistic Regression Models*. 
nominal variables were coded with dummy variables indicated in the table. Table 4.1 summarizes the results.

Table 4.1

Logistic Regression Coefficients (Odds Ratio in Parentheses) Stronger-personal Math Identity Dissonance: All Students (n=16,904)

<table>
<thead>
<tr>
<th></th>
<th>Model I</th>
<th>Model II</th>
<th>Model III</th>
<th>Model IV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Student Level Demographic Variables</strong></td>
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</tr>
<tr>
<td>Female</td>
<td>-0.45***</td>
<td>-0.45***</td>
<td>-0.44***</td>
<td>-0.40***</td>
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<td></td>
<td>(0.64)</td>
<td>(0.64)</td>
<td>(0.65)</td>
<td>(0.67)</td>
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<td>Race (Ref: White)</td>
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<td>-0.05</td>
<td>-0.09</td>
<td>-0.16</td>
<td>-0.17</td>
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<td></td>
<td>(0.95)</td>
<td>(0.92)</td>
<td>(0.85)</td>
<td>(0.84)</td>
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<td>Hispanic</td>
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<td>0.06</td>
<td>0.03</td>
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<td></td>
<td>(1.06)</td>
<td>(1.06)</td>
<td>(1.03)</td>
<td>(1.01)</td>
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<tr>
<td>Asian</td>
<td>-0.22*</td>
<td>-0.12</td>
<td>-0.15</td>
<td>-0.16</td>
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<td></td>
<td>(0.80)</td>
<td>(0.89)</td>
<td>(0.86)</td>
<td>(0.85)</td>
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<tr>
<td>Other Race</td>
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<td>-0.06</td>
<td>-0.07</td>
<td>-0.10</td>
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<tr>
<td></td>
<td>(0.94)</td>
<td>(0.95)</td>
<td>(0.93)</td>
<td>(0.90)</td>
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<tr>
<td>Urbanicity (Ref: City)</td>
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<td>Not City</td>
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<td>0.07</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>(1.04)</td>
<td>(1.07)</td>
<td>(1.07)</td>
<td>(1.08)</td>
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<tr>
<td>Socioeconomic Status</td>
<td>-0.24***</td>
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<td>-0.15***</td>
<td>-0.13**</td>
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<td></td>
<td>(0.79)</td>
<td>(0.85)</td>
<td>(0.86)</td>
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<td><strong>Student Level Prior Math Achievement Variables</strong></td>
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<tr>
<td>Standardized Test Score</td>
<td>-0.01</td>
<td>-0.01**</td>
<td>-0.01*</td>
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<tr>
<td></td>
<td>(1.00)</td>
<td>(0.99)</td>
<td>(0.99)</td>
<td></td>
</tr>
<tr>
<td>Final Math Grade in Grade 8</td>
<td>-0.01</td>
<td>-0.07*</td>
<td>-0.04</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.99)</td>
<td>(0.94)</td>
<td>(0.96)</td>
<td></td>
</tr>
<tr>
<td>8th Grade Math Class (Ref: 8th Grade Math/Pre-Algebra)</td>
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<td></td>
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<tr>
<td>Took Algebra</td>
<td>-0.30***</td>
<td>-0.30***</td>
<td>-0.29***</td>
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<tr>
<td></td>
<td>(0.75)</td>
<td>(0.74)</td>
<td>(0.75)</td>
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<tr>
<td>Took Advanced Math course</td>
<td>-0.64***</td>
<td>-0.66***</td>
<td>-0.65***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.53)</td>
<td>(0.52)</td>
<td>(0.52)</td>
<td></td>
</tr>
<tr>
<td>Took Other Math Course</td>
<td>-0.20</td>
<td>-0.20</td>
<td>-0.20</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.82)</td>
<td>(0.82)</td>
<td>(0.82)</td>
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<tr>
<td><strong>Student Level Attitude Towards Math Variables</strong></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Math Utility Scale</td>
<td>-0.03</td>
<td>-0.01</td>
<td>-0.01</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.97)</td>
<td>(0.99)</td>
<td>(0.99)</td>
<td></td>
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<tr>
<td>Math Self-Efficacy Scale</td>
<td>0.07*</td>
<td>0.10**</td>
<td>0.10**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.08)</td>
<td>(1.10)</td>
<td>(1.10)</td>
<td></td>
</tr>
<tr>
<td>Math Interest Scale</td>
<td>0.18***</td>
<td>0.22***</td>
<td>0.22***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.20)</td>
<td>(1.25)</td>
<td>(1.25)</td>
<td></td>
</tr>
<tr>
<td><strong>Student Level Attitudes Towards School In General</strong></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>School Belonging Scale</td>
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<td>-0.10***</td>
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<tr>
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<td></td>
<td></td>
<td>(0.90)</td>
<td></td>
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<tr>
<td>School Engagement Scale</td>
<td></td>
<td></td>
<td>-0.10***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.91)</td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-2.10***</td>
<td>-1.71***</td>
<td>-1.28***</td>
<td>-1.41***</td>
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<tr>
<td></td>
<td>7</td>
<td>12</td>
<td>15</td>
<td>17</td>
</tr>
<tr>
<td>$\chi^2$</td>
<td></td>
<td></td>
<td>10091.31</td>
<td>10048.26</td>
</tr>
<tr>
<td>-2 Log likelihood</td>
<td>10091.31</td>
<td>10048.26</td>
<td>9993.74</td>
<td>9966.34</td>
</tr>
<tr>
<td>Fkerke R$^2$</td>
<td>0.02</td>
<td>0.02</td>
<td>0.03</td>
<td>0.03</td>
</tr>
</tbody>
</table>

*p ≤ 0.05  **p ≤ 0.01  ***p ≤ 0.001
4.2.1. **Demographic domain variables.** Models I through IV show significant gender differences in MID$_p$ expression. When controlling for all other variables in the study, female respondents are 33 percent less likely to express MID$_p$ than their male counterparts. This is expressed in an odds ratio of $0.67/1$. Calculating the reciprocal of the odds ratio shows male students are 49 percent more likely than females to express MID$_p$. This is expressed in the odds ratio $1/0.67$. In summary, the probability that stronger-personal math identity dissonance is expressed significantly increases when the predictor variable is male. Males are more likely to agree with the statement “you see yourself as a math person,” while disagreeing with the statement “others see you as a math person.”

Based on the significant ($p \leq 0.001$) gender differences influencing the likelihood of MID$_p$, subsequent analyses of MID$_p$ measure female and male students in independent models. Models IX through XII, summarized in Table 4.3, and Models XVII through XX summarized in Table 4.5, repeat the above analysis for females and males separately.

Models I through IV illustrate that school locale is not a particular relevant factor in the expression of MID$_p$ in the entire population of students. When controlling only for demographic variables in Model I, the probability of MID$_p$ expression decreases by 20 percent when the predictor variable is Asian. The significance of race disappears completely, however, when controlling for achievement variables in Model II.

Models I through IV illustrate that school locale is not a factor in the expression of MID$_s$. Socioeconomic status (SES), however, is a significant predictor of MID$_p$ in each of the four models. For every unit increase in SES, the probability of MID$_p$ decreases by
a factor of 0.88, or 12 percent. Another interpretation of this is that lower SES has a positive effect on the probability that a student expresses MID<sub>p</sub>. In summary, the probability of a randomly selected student agreeing with the statement “you see yourself as a math person” while disagreeing with the statement “others see you as a math person” significantly increases with lower SES.

4.2.2 Math achievement domain variables. Model II introduces math achievement variables. In addition to controlling for the demographic variables, students’ performance on the HSLS:09 algebra assessment, students’ final math grade in eighth grade math course, and students’ highest level of math course in the eighth grade are included in Model II.

When controlling for all other variables in the study, it was shown that higher performance on the standardized algebra assessment of HSLS:09 lowers the probability that MID<sub>p</sub> is expressed. The standardized theta score of the algebra test ranged from 24.3 to 81.8, with a standard deviation of 10. For every unit increase in the standardized test score the odds that MID<sub>p</sub> is expressed decreases by 1 percent. Though this may seem small at first glance, it’s important to note that this implies that when the predictor variable is a standardized theta score one standard deviation below the mean, the odds of MID<sub>p</sub> expression increases by a factor of more than 10 percent relative to an average standardized theta score.

Students’ final math grade in their eighth grade math course is a significant predictor of the probability of MID<sub>p</sub> when controlling for demographics and math mindsets. The likelihood of MID<sub>p</sub> decreases with higher grades. When controlling for
school mindset domain variables in Model IV, final grade in eighth grade math course ceases to be significant.

The eighth grade math course that a student was enrolled in proves to be a highly significant variable in the expression of MID_p. Compared to eighth grade math and pre-algebra, a student enrolled in Algebra decreases the odds of MID_p by a factor of 0.75, or 25 percent. Furthermore, a student enrolled in an even higher level math course, which would include geometry, Algebra 2, and beyond, decreases the odds that MID_p is expressed by a factor of 0.52, or 48 percent. For students enrolled in other math courses, not characterized by their specific level, there is no significant change in the odds that MID_p is expressed.

In summary, this analysis shows that the probability of MID_p expression as a function of student algebra ability and math track is significant. The regression model shows that the higher students score on the algebra assessment the less likely they are to express MID_p. Similarly, students in higher math tracks are less likely to express MID_p relative to their counterparts in lower tracked math classes.

4.2.3. Math mindset domain variables. Model III introduces three independent variables regarding student math mindsets. Each variable is a continuous scale variable that was created by the primary HSLS:09 researchers. The math utility scale measures student beliefs about the usefulness of their current math course to their present and future lives. The scale of math self-efficacy measures student beliefs in their ability to be successful in their current math course. The scale of student math interest measures student interest in current math courses. Each of the scales was standardized to a mean of 0 and a standard deviation of 1.
A student’s perception of the usefulness of his current ninth grade math course is an insignificant predictor in the model. A unit increase in student self-efficacy beliefs, however, increases the odds that MID\textsubscript{p} will be expressed by a factor of 1.10, or 10 percent when controlling for all other variables in the study. As a unit increase corresponds to 1 standard deviation, it can be concluded that when the predictor variable is high self-efficacy there is a significant increase in the probability of MID\textsubscript{p} expression relative to predictor variables of lower self-efficacy.

When controlling for all other variables in the study, student interest in current math courses has a significant influence on the probability that MID\textsubscript{p} is expressed. A unit increase in the scale of math interest corresponding to 1 standard deviation increases the odds of MID\textsubscript{p} by a factor of 1.25, or 25 percent.

In summary, the probability of a randomly selected student from the sample agreeing with the statement “you see yourself as a math person,” while disagreeing with the statement “others see you as a math person,” increases if that student expresses higher math self-efficacy, and it also increases with higher interest in math courses.

4.2.4 School mindset domain variables. Both school belonging and school engagement are significant (p ≤ 0.001) when controlling for all other variables in the study. The school belonging scale is a measure of perceptions of school belonging. It is standardized to a mean of 0 and a standard deviation of 1. Higher values correspond to a stronger sense of school belonging expressed through feeling safe at school, feeling proud to be a part of the school, and valuing high grades. The school engagement scale, also standardized to a mean of 0 and standard deviation of 1, is a scale of student
perceptions of engagement in the dominant practices associated with being a student. These include attending class prepared and on time.

An increase in 1 standard deviation on the school belonging scale, decreases the odds that MID\(p\) is expressed by a factor of .90, or 10 percent. Similarly, as school engagement increases by 1 unit, equivalent to 1 standard deviation, the odds that MID\(p\) is expressed decrease by a factor of .91, or 9 percent.

In summary, students who adhere to the cultural norms of school, expressed on the school belonging and school engagement scales, are less likely to express MID\(p\) relative to those students with a lower value of school belonging or school engagement.

4.2.5 Models I through IV summary. The Nagelkerke R\(^2\) value of .03 indicates the chosen variables account for only 3 percent of the variance in MID\(p\). This model, however, identifies a number of student-level variables that significantly influence the probability that MID\(p\) is expressed. Significant predictor variables include: gender, SES, algebra assessment scores, eighth grade math course, math self-efficacy, math interest, school belonging, and school engagement. These can be interpreted as parameters used to form a portrait of a student who expresses MID\(p\). These results will be further discussed in chapter 5.

4.3 Analysis and Interpretation of Stronger-Social Math Identity Dissonance (MID\(_s\)) for All Students

Models V through VIII compare ninth grade students who exhibit MID\(_s\) to students who do not. MID\(_s\) is the case where a student disagrees with the statement “you are a math person” while agreeing with the statement “others see you as a math person.” Logistic regression analysis was conducted over four separate models to examine the
influence of predictor variables on the probability that MID$_3$ is expressed. With each model, new domain variables are added to control for a greater number of possible predictors. Table 4.2 summarizes the results of the logistic regression analysis for n=16,904.
Table 4.2
Logistic Regression Coefficients (odds ratio in parentheses) Stronger-social Math Identity Dissonance: All Students (n=16,904)

<table>
<thead>
<tr>
<th></th>
<th>Model V</th>
<th>Model VI</th>
<th>Model VII</th>
<th>Model VIII</th>
</tr>
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<td><strong>Student Level Demographic Variables</strong></td>
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<td>0.32***</td>
<td>0.32***</td>
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<tr>
<td>Black</td>
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<td>0.19*</td>
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<td><strong>Student Level Prior Math Achievement Variables</strong></td>
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<tr>
<td>Standardized Test Score</td>
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<td>Final Math Grade in Grade 8</td>
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<td>(1.01)</td>
</tr>
<tr>
<td>8th Grade Math Class (Ref: 8th Grade Math/Pre-Algebra)</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Took Algebra</td>
<td>0.15*</td>
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<td>0.14*</td>
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</tr>
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<tr>
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</tr>
<tr>
<td>Took Other Math Course</td>
<td>0.03</td>
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<td><strong>Student Level Attitude Towards Math Variables</strong></td>
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<tr>
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<td>-0.34***</td>
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<td>.01</td>
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<td>0.13***</td>
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<td>-2.91***</td>
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</table>

*p ≤ 0.05              ** p ≤ 0.01              *** p ≤ 0.001
4.3.1 Demographic domain variables. Models V through VIII show significant gender differences in MID, expression. When controlling for all other variables in the study, female respondents are 32 percent more likely to express MID than their male counterparts. This is expressed in an odds ratio of 1.32/1. Calculating the reciprocal of the odds ratio shows male students are 24 percent less likely than females to express MID. This is expressed in the odds ratio 1/1.32. In summary, the probability that stronger-social math identity dissonance is expressed significantly increases when the predictor variable is female. Females are more likely to disagree with the statement “you see yourself as a math person” while agreeing with the statement “others see you as a math person.”

A comparison of results summarized in Table 4.1 and Table 4.2 shows that it is significantly more likely for males to express MID, whereas females are much more likely to express MID. This gender difference in the expression of MID will be the topic of much discussion in the next chapter.

When controlling for all other variables, race is a highly relevant factor in the expression of MID. Relative to their White counterparts, the odds of MID expression increases by 35% for Black students, 23% for Hispanic students, 45% for Asian students, and 37% for students who identify as another race or as more than one race. This shows that race variables have a significant impact on the probability that a student chosen at random expresses MID.

Models V through VIII illustrate that school locale is not a factor in the expression of MID. Socioeconomic status (SES), however, is a significant predictor of MID when controlling for race and math achievement. Unit increases in SES increase
the odds that MID₃ is expressed by more than 10 percent. When math mindsets and school mindsets are controlled for in models VII and VIII, however, SES is no longer significant.

4.3.2. Math achievement domain variables. Model VI introduces math achievement variables. In addition to controlling for the demographic variables, included in Model VI are student performance on the HSLS:09 algebra assessment, students’ final math grade in their eighth grade math course, and students’ highest level of math course in the eighth grade.

When controlling for all other variables in the study, math achievement did not have a particularly strong influence on the probability that MID₃ is expressed. Scores on the algebra assessment and students’ final grade in their eighth grade math class were not significant predictors of MID₃. When controlling for all other variables in the study, the odds of MID₃ was found to increase by 15 percent for students who took algebra in the eighth grade, relative to those students who took lower tracked math courses.

4.3.3 Math mindset domain variables. Model VII introduces the three independent variables regarding student math mindsets. Scales of math utility, math self-efficacy, and math interest were each standardized to a mean of 0 and a standard deviation of 1.

When controlling for all other variables in the study, neither a student’s perception of the usefulness of the current ninth grade math course, nor a student’s self-efficacy belief influences the probability that MID₃ is expressed.

When controlling for all other variables in the study, student interest in current math courses has a significant influence on the probability that MID₃ is expressed. A unit
increase in the scale of math interest, corresponding to 1 standard deviation, decreases the odds of MID_s by a factor of 0.71, or 29 percent.

In summary, the probability of a randomly selected student from the sample agreeing with the statement “you see yourself as a math person,” while disagreeing with the statement “others see you as a math person,” decreases if that student expresses interest in her math course but is not influenced by perceptions of utility or self-efficacy.

4.3.4. School mindset domain variables. School belonging is not a significant predictor of the probability that MID_s is expressed. The school engagement scale, however, does influence MID_s. This analysis shows that an increase of 1 standard deviation in the school engagement scale increases the odds of MID_s by a factor of 14 percent. Students who come to class on time and are prepared are more likely than students who do not come to class on time and are not prepared to disagree with the statement “you see yourself as a math person,” while agreeing with the statement “others see you as a math person.”

4.3.5 Models V through VIII Summary. The Nagelkerke R^2 value of .03 indicates the chosen variables account for only 3 percent of the variance in MID_s. This model, however, identifies a number of student-level variables that significantly influence the probability that MID_s is expressed. Significant predictor variables include: gender, race, math interest, and school engagement. These variables can be interpreted as parameters used to form portraits of students most likely to expresses MID_s. A comparison of Table 4.1 and 4.2 shows two different student portraits taking shape.
4.4 Analysis and Interpretation of MID_p Among Female Students

Models IX through XII use logistic regression analysis to examine variables that influence MID_p in a nationally representative sample (n=8,508) of ninth grade females. Intra-group comparisons of females who express MID_p to females who do not express MID_p are assessed. Table 4.3 summarizes the results of the logistic regression models.
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<tr>
<th></th>
<th>Model IX</th>
<th>Model X</th>
<th>Model XI</th>
<th>Model XII</th>
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<td>-0.01</td>
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<td>(0.97)</td>
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<td>0.09</td>
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<td>(1.14)</td>
<td>(1.14)</td>
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<td>(1.06)</td>
</tr>
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<td>(0.84)</td>
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<td>(1.01)</td>
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<td>-0.02***</td>
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</tr>
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<td>-0.27**</td>
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<td><strong>Student Level Attitudes Towards School In General</strong></td>
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<td>0.02</td>
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</table>

*p ≤ 0.05  ** p ≤ 0.01  *** p ≤ 0.001
4.4.1 Demographic domain variables. When measuring the impact that demographic variables have in predicting the probability that $\text{MID}_p$ will be expressed in the population of ninth grade female students, little significance is discovered. Neither race nor urbanicity prove to be meaningful factors. When controlling for race and urbanicity, SES is significant. The odds that $\text{MID}_p$ is expressed decreases by a factor of 18 percent for every unit increase in SES. Controlling for math mindset and school mindset domain variables in models XI and XII, SES ceases to be a significant predictor of $\text{MID}_p$ in ninth grade female students.

4.4.2 Math achievement domain variables. Math achievement affects $\text{MID}_p$ expression among ninth grade females. For female students, increases in the standardized score of the HSLS:09 algebra assessment decreased the odds that $\text{MID}_p$ is expressed by a factor of 0.98, or 2 percent for every unit increase in score. Increases in scores comparable to 1 standard deviation decrease the odds that $\text{MID}_p$ is expressed by a factor of 0.82, or 18 percent.

Female students tracked into more challenging math courses are less likely to express $\text{MID}_p$. For females enrolled in algebra, the odds that they express $\text{MID}_p$ decreases by a factor of 0.78 relative to their counterparts enrolled in eighth grade math and pre-algebra. Additionally, female students who were enrolled in more advanced math courses in the eighth grade were even less likely to express $\text{MID}_p$. Relative to their counterparts in eighth grade math and pre-algebra, the odds that $\text{MID}_p$ is expressed decreases by a factor of 0.41, or 59 percent. The final grade in eighth grade math class was not a significant predictor of $\text{MID}_s$ expression in females.
4.4.3 Math mindset domain variables. Model XI introduces the three independent variables describing students’ math mindsets. Scales of math utility, math self-efficacy, and math interest, standardized to a mean of 0 and a standard deviation of 1, are introduced.

When controlling for all other variables in the study, a female’s perception of the usefulness of her current ninth grade math course does not change the probability that \( \text{MID}_p \) is expressed. When controlling for all other variables, unit increases in female’s self-efficacy beliefs increase the odds that \( \text{MID}_p \) is expressed by a factor of 1.16, or 16 percent.

When controlling for all other variables in the study, a female student’s interest in her current math course has a significant influence on the probability that \( \text{MID}_s \) is expressed. A unit increase in the scale of math interest, corresponding to 1 standard deviation, increases the odds of \( \text{MID}_p \) by a factor of 1.30, or 30 percent.

4.4.4 School mindset domain variables. Among female students, both school belonging and school engagement are significant predictors of \( \text{MID}_p \) when controlling for all other variables in the study. As the school belonging scale increases by 1 unit, equivalent to 1 standard deviation, the odds that \( \text{MID}_p \) is expressed decreases by a factor of .90, or 10 percent. Similarly, as school engagement increases by 1 unit, the odds that \( \text{MID}_s \) is expressed decreases by a factor of .83, or 17 percent.

4.4.5 Models IX through XII Summary. Overall, the Nagelkerke \( R^2 \) value is 0.03. This implies that the chosen variables account for only 3 percent of the variance in \( \text{MID}_p \) among female students. A number of independent variables, however, were found to be significant. Intra-group differences of the likelihood of \( \text{MID}_p \) expression among
females are influenced by their HSLS:09 algebra assessment, eighth grade math course, math self-efficacy, math interest, school belonging, and school engagement.

4.5 Analysis and Interpretation of MID\textsubscript{s} Among Female Students

Models XIII through XVI examine independent variables that predict changes to the probability that MID\textsubscript{s} is expressed in a nationally representative sample of ninth grade female students. Table 4.4 summarizes the results.
<table>
<thead>
<tr>
<th>Table 4.4</th>
<th>Logistic Regression Coefficients (odds ratio in parentheses) Stronger-social Math Identity Dissonance: Female Students (n=8,508)</th>
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<td>Model XIII</td>
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*p ≤ 0.05  ** p ≤ 0.01  *** p ≤ 0.001
4.5.1 Demographic domain variables. Relative to their white female counterparts, female students of color are significantly more likely to express MID$_s$. When controlling for all other variables in the study, for each racial category considered, including Black, Hispanic, Asian, and “other race students,” the odds that MID$_s$ is expressed increases by a factor of more than 1.40, or 40 percent. Neither SES nor urbanicity were significant variables to the probability of MID$_s$ expression for female students.

4.5.2 Math achievement domain variables. Model XIV introduces prior math achievement to the analysis of MID$_s$ in female students. In addition to controlling for demographic variables, female performance on the HSLS:09 algebra assessment, final math grade in the eighth grade math course, and highest level of math course in the eighth grade are included.

When controlling for all other variables in the study, math achievement was not a particularly significant predictor of the probability that MID$_s$ would be expressed. Higher scores on the algebra assessment, higher final grade in eighth grade math class, and being tracked in algebra rather than the lower math track did increase the probability that MID$_s$ would be expressed when controlling for demographics and math mindsets. These variables, however, ceased to be significant when controlling for school mindsets.

4.5.3 Math mindset domain variables. Model XV introduces math mindset variables to investigate their influence on MID$_s$ expression among female students. Math mindset variables include: scales of math utility, math self-efficacy, and math interest.
When controlling for all other variables in the study, neither a female student’s perception of the usefulness of her current ninth grade math course nor her self-efficacy beliefs influence the probability that MID is expressed.

When controlling for all other variables in the study, a female’s interest in her current math course has a significant influence on the probability that MID is expressed. A unit increase in the scale of math interest, corresponding to 1 standard deviation, decreases the odds of MID by a factor of 0.68, or 32 percent among ninth grade female students.

4.5.4 Attitudes towards school. The scale of student school belonging was found to be insignificant in the Model XVI. When controlling for all other variables in the study, however, the scale of school engagement is highly significant ($p \leq 0.001$). The odds that MID is expressed by female students increases by a factor of 1.18, or 18 percent for every unit increase, corresponding to 1 standard deviation, in the scale of school belonging.

4.5.5 Models XIII through XVI summary. Overall, the Nagelkerke $R^2$ value is 0.04. This implies that the chosen variables account for only 4 percent of the variance in MID among ninth grade females. A number of independent variables, however, were found to greatly affect the odds that MID is expressed. These include race, math interest, and school engagement.

4.6 Analysis and Interpretation of MID Among Male Students

Models XVII through XX use logistic regression analysis to examine variables that influence MID in a nationally representative sample (n=8,396) of ninth grade males.
Intra-group comparisons of males who express MID\(_p\) to males who do not express MID\(_p\) are assessed. Table 4.5 summarizes the results of the logistic regression models.

Table 4.5

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<tr>
<th>Logistic Regression Coefficients (odds ratio in parentheses) Stronger-personal Math Identity Dissonance: Male Students (n=8,396)</th>
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<th>Model XVIII</th>
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<th>Model XX</th>
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<td>Took Algebra</td>
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<td>-0.53**</td>
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<tr>
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<td>0.02</td>
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* \(p \leq 0.05\)  ** \(p \leq 0.01\)  *** \(p \leq 0.001\)
4.6.1 Demographic domain variables. When measuring the impact that demographic variables have in predicting the probability that \( \text{MID}_p \) will be expressed in the population of ninth grade male students interesting differences are observed. The odds of \( \text{MID}_p \) expression decrease by 24 percent for Black students relative to their white male counterparts, but no other significant differences are measured between races. Urbanicity is not a significant variable, but SES is. When controlling for all other variables in the study, the odds that \( \text{MID}_p \) is expressed decreases by a factor of 0.84, or 16 percent, with every unit increase in SES.

4.6.2 Math achievement domain variables. For male students, neither the standardized score of the HSLS:09 algebra assessment nor their grades from eighth grade math class influenced \( \text{MID}_p \). Male students tracked into more challenging math courses are less likely to express \( \text{MID}_p \). For male students enrolled in Algebra, the odds that they express \( \text{MID}_p \) decreases by a factor of .74, or 26 percent relative to their counterparts enrolled in eighth grade math or pre-algebra. Additionally, male students who were enrolled in more advanced math courses in the eighth grade were even less likely to express \( \text{MID}_p \). Relative to their counterparts in eighth grade math or pre-algebra, the odds of \( \text{MID}_p \) decreased by a factor of 0.59, or 41 percent for those students in the highest math tracks.

4.6.3 Math mindset domain variables. Model XIX introduces the three independent variables describing student math mindsets. It introduced scales of math utility, math self-efficacy, and math interest into the models. Each of these variables was standardized to a mean of 0 and a standard deviation of 1.
When controlling for all other variables in the study, a male’s perception of the usefulness of his current ninth grade math course does not change the probability that MID$_p$ is expressed. Similarly, when controlling for all other variables a male’s self-efficacy beliefs do not influence MID$_p$.

When controlling for all other variables in the study, a male student’s interest in his current math course has a significant influence on the probability that MID$_s$ is expressed. A unit increase in the scale of math interest, corresponding to 1 standard deviation, increases the odds of MID$_p$ by a factor of 1.20, or 20 percent.

**4.6.4 School mindset domain variables.** School mindset variables are introduced in model XX. The scale of school belonging and engagement were each standardized to a mean of 0 and a standard deviation of 1. When controlling for all other variables in the study, increases of 1 unit on the school belonging scale decrease the odds that MID$_p$ is expressed by 9 percent. School engagement does not influence MID$_p$ expression among males.

**4.6.5 Models XVII through XX summary.** Overall, the Nagelkerke $R^2$ value is 0.02. This implies that the chosen variables account for only 2 percent of the variance in MID$_p$ among male students. A number of independent variables, however, were found to be significant. Intra-group differences of the likelihood of MID$_p$ expression among males are influenced by SES, their eighth grade math course, math interest, and school belonging. The odds of MID$_p$ expression among male students also significantly decreased for Black students, relative to their White male counterparts.
4.7 Analysis and Interpretation of MIDₚ Among Male Students

Models XXI through XXIV use logistic regression analysis to examine variables that influence MIDₚ in a nationally representative sample (n=8,396) of ninth grade males. Intra-group comparisons of males who express MIDₚ to males who do not express MIDₚ are assessed. Table 4.6 summarizes the results of the logistic regression models.
Table 4.6
Logistic Regression Coefficients (odds ratio in parentheses) Stronger-social Math Identity Dissonance: Male Students (n=8,396)

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<th>Model XXII</th>
<th>Model XXIII</th>
<th>Model XXIV</th>
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<td>Nagelkerke $R^2$</td>
<td>0.00</td>
<td>0.01</td>
<td>0.02</td>
<td>0.02</td>
</tr>
</tbody>
</table>

* p ≤ 0.05  ** p ≤ 0.01  *** p ≤ 0.001
4.7.1 Demographic domain variables. When controlling for all other variables in the study, Asian males are 46% more likely to express MIDₕ than their white male counterparts. For Black and Hispanic males, there is no significant difference measured in their expression of MIDₕ. SES is not a significant predictor of MIDₕ for male students nor is urbanicity.

4.7.2 Math achievement domain variables. When controlling for all other variables in the study, math achievement domain variables are not significant predictors of the probability of MIDₕ for male students.

4.7.3 Math mindset domain variables. A male student’s interest in his current math course is a significant predictor of MIDₕ. For every unit increase in the math interest scale, the odds that MIDₕ is expressed decreases by 26 percent. Neither math utility nor math self-efficacy are significant predictors of the probability of MIDₕ in male students.

4.7.4 School mindset domain variables. When controlling for all other variables in the study, increases of 1 unit on the school engagement scale increase the odds of MIDₕ by 10 percent among male students. School belonging is not a significant variable for predicting MIDₕ in ninth grade males.

4.7.5 Models XXI through XXIV summary. Overall, the Nagelkerke R² value is 0.02, which means that the chosen variables account for only 2 percent of the variance in MIDₕ. Several independent variables were found to be significant. Asian males are more likely to express MIDₕ relative to their White male counterparts. Math interest and school engagement are both significant predictors of MIDₕ in males.
4.8 Summary of Results

Across 24 models, the probability of encountering math identity dissonance in a random student from the sample was measured as a function of demographic, math achievement, math mindset, and school mindset domain variables. Numerous independent variables proved to have a significant impact on the expression of both stronger-personal math identity dissonance and stronger-social math identity dissonance. Though results from the logistic regression models show that much of the variance remains unaccounted for, the differences in MID expression from the included variables show important patterns across all four domains. In the following chapter, these parameters will be discussed in the context of relevant literature.
Chapter 5 Discussion of Results

5.1 Introduction

The purpose of the current study was to determine differences in the odds of MID expression from a number of predictor variables. Using multivariate logistic regression models, repeated measures of the odds of both stronger-personal math identity dissonance (MID\textsubscript{p}) and stronger-social math identity dissonance (MID\textsubscript{s}) were calculated as a function of 17 covariates grouped in four domains. Salient findings from the current study include significant differences in MID expression by demographics (e.g., gender, race, and SES), math achievement (e.g., test scores and ability tracking), math mindsets (e.g., self-efficacy and interest), and school mindsets (e.g., belonging and engagement). These results will be discussed below. Important distinctions will also be made between female and male sample members based on results of regression models that made intra-group gender comparisons for both forms of MID.

5.1.1 Math identity dissonance and demographics among all students. When controlling for all other variables in the study I found that females are more likely to embrace the belief that others see them as math persons while simultaneously maintaining the personal belief that they are not math persons (MID\textsubscript{s}). These results align with previous findings, which have consistently shown females have a weaker math self-concept than males (Catsambis, 1994; Pajares & Miller, 1994; Nosek et al., 2002; Wigfield et al., 1997). Catsambis (1994) used a nationally representative sample to show that females generally have more negative attitudes towards mathematics. Wigfield et al. (1997) confirmed earlier findings (Marsh et al., 1991) that over the course of middle
school and into high school females have weaker competency beliefs and less interest in mathematics than males. Nosek and colleagues (2002) showed that females implicitly endorse negative stereotypes about their belonging in math. Chipman (2005) has argued that gender discrepancies in self-reported competence beliefs may be a result of social conditioning in which it is less acceptable for females to express high levels of confidence in mathematics. All of these studies are consistent with the current findings that females are more likely to convey stronger-social math identity dissonance.

The current finding contributes to previous research by showing that females are more likely than males to acknowledge being recognized by others as a math person but disavow being a math person as part of their personal identity. This has implications for interventions geared towards encouraging more females to enter into math and math-related fields. Past research focused on attitudes and beliefs about math that are more task specific. The current findings suggest that beyond self-efficacy and math utility beliefs, females need more opportunities to align their personal identities to school mathematics practices. Further implications will be discussed in the next chapter.

Results from the current study show that males are much more likely to express stronger-personal math identity dissonance than females. These results align to previous findings that show males have stronger self-competence beliefs and more interest in mathematics (Marsh et al., 1991; Wigfield et al., 1997). Adolescent males are consistently observed expressing higher self-assessments in math (Correll, 2004) and higher overall self-esteem than their female counterparts (Wigfield et al., 1991). The current findings contribute to previous research by showing that males are likely to
acknowledge that others do not see them as math persons but express positive personal identity beliefs regardless.

Controlling for all other variables in the study, no significant race differences were measured in the likelihood that MID$_p$ is expressed. This contradicts the hypothesis that Black and Hispanic students are more likely to assert being a math person regardless of how others see them. This hypothesis was made based on previous findings that Black and Hispanic students will maintain positive math self-concepts independent of achievement and fewer opportunities for meaningful participation (Catsambis, 1994; Oakes, 1990). The current results also seem to contradict McGee’s (2009) findings that resilience among Black math students is motivated by a prove-them-wrong mindset. In McGee’s analysis, Black students consistently expressed that they believed others did not recognize them as the math people they saw themselves to be.

Inconsistent results between McGee’s study and the current study are most likely attributable to differing methodologies and sample characteristics. McGee (2009) employed in-depth interviews to focus on a small sample (n=23) of high performing engineering and mathematics students at the university and graduate level. The current study did not make intra-group comparisons of Black students and was unable to differentiate between higher and lower achieving Black students. It is reasonable to believe within the subsample of Black students, increased likelihood of stronger personal math identity dissonance would be observed with higher achievement.

Race was a robust predictor of the likelihood of stronger-social math identity. Black, Hispanic, Asian, and students of other races were found to be much more likely to
express stronger-social math identity dissonance than their White counterparts. These results were anticipated for Asian students who must contend with positive stereotypes about their math ability (Cheryan & Bodenhausen, 2000; Shih et al., 1999). Increased odds of MID, however, were not expected to be attributed to Black and Hispanic students who must contend with pervasive negative stereotypes about their math ability.

One explanation for the current finding can be found in the stereotype threat literature. Expressions of MID can be interpreted as the disidentifying described by Steele (1997) and Spencer et al., (1999), which occurs when individuals distance themselves from identifying with a domain that invites stereotype threat. The current results show that by the ninth grade, the threat of confirming negative stereotypes is sufficiently internalized. Despite being encouraged to take on positive math identities, minority students and females are more likely to maintain distance from personally identifying with math.

Interestingly, this trend is not maintained for lower SES students, who have also been observed to experience considerable stereotype threat in the practice of mathematics (Croizet & Claire, 1998). SES is not a significant predictor of MID. Significant SES differences, however, are observed in stronger-personal MID. As was predicted, higher SES decreases the likelihood of MID. This can be explained in the context of Oyserman’s (2012) study, which argues that higher SES students generally have an easier time maintaining identity-congruence in school settings.

Additional findings of demographic differences will be discussed in intra-group comparisons of males and females.
5.1.2 *Math identity dissonance and math achievement among all students.* I hypothesized that, in general, measures of higher math achievement would decrease the odds of stronger-personal MID and increase the odds of stronger-social MID. In the case of MID\(p\), results of logistic regression analysis confirm the hypothesis.

Abreu and Cline (2003) claimed that external evaluations of student participation in mathematics shape students’ social math identity. The present findings confirm this. Logistic regressions in Models I through IV showed that odds of stronger-personal MID increase with lower math performance. Despite maintaining beliefs in being math persons, students with lower test results and in lower ability groups were more likely to recognize that others do not see them as math people. Both lower test scores and lower ability tracking significantly increased the odds of MID\(p\). Grades on the other hand were not a significant predictor.

These results seem to contradict Chiu et al. (2008) who found that students compare themselves more to other students within their same math track than across tracks. Chiu and colleagues (2008) argued that grades, rather than math track, had the stronger influence on students’ math self-concepts. The current study indicates that students in lower ability tracks may maintain a strong personal math identity, but they are well aware that others do not recognize them as math people.

The insignificance of grades as a predictor of MID can be explained through a review of academic mindset literature (Farrington et al., 2012), which makes the case that grades and identity are strongly correlated. This implies that grades most likely align well with coherent math identities. Stronger grades likely imply stronger personal and
social math identities, and weaker grades likely predict weaker personal and social math identities. This finding also agrees with the predication that high grades contribute to Black and Hispanic students’ positive self-assessments in math despite lower standardized performance scores (Catsambis, 1994).

Lower test scores were found to increase the probability of \( \text{MID}_p \). For students scoring 1 standard deviation below the average on the HSLS:09 algebra assessment, the odds of expressing \( \text{MID}_p \) increase by a factor of 1.11 relative to an average student’s score. Prior studies have used math mindsets as a predictor of test scores. The current study indicates that test results convey to students how others see them as math people, but lower scoring students are more likely to resist the labels associated with their performance.

Overall, achievement domain variables show that students with lower performance in the dominant practices of school mathematics know that this has implications for how they are seen by others. The complexity of MID and achievement is best summed up by two of the ninth graders, Samuel and Julieta, who were featured in Zavala’s (2012) ethnography and discussed earlier. Samuel is high achieving in math but states, “I’m just not a math person” (p. 6). Julieta struggles mightily but loves math. Working with Samuel, Julieta finds herself feeling “not out of the circle, but instead inside” (p. 58). Both Samuel and Julieta are aware of how others see them in practicing math, but they both express agency in resisting the achievement labels ascribed to them by others.
5.1.3 Math identity dissonance and math mindsets among all students. Contrary to what was predicted, the odds of $\text{MID}_p$ increased with higher self-efficacy when controlling for all other variables in the study. Self-efficacy was not a significant predictor of stronger-social math identity dissonance. Earlier studies (Pajares & Miller, 1994) showed a strong correlation between self-efficacy and math self-concept beliefs. Because self-efficacy was shown to be a strong predictor of achievement, however, I hypothesized that higher self-efficacy would result in both higher personal and social math identity. My findings imply that task specific competency beliefs align more with personal identity than with social identity.

When controlling for all other variables in the study, math utility beliefs were not significant to MID expression. Interest in current math class, however, was highly predictive of both $\text{MID}_p$ and $\text{MID}_s$. The odds of stronger-personal MID increased by a factor of 25% for every unit increase in the scale of math interest. Conversely, the odds of stronger-social math identity dissonance decreased by 29% for every unit increase in the scale of math interest. These findings are consistent with Dewey’s equation of interest to personal identity, which is fundamental to the theoretical construct of MID.

5.1.4 Math identity dissonance and school mindsets among all students. When controlling for all other variables in the study, students who reported higher levels of school engagement were more likely to express stronger-social MID and less likely to express stronger-personal MID. This is consistent with previous research that suggests that many students with high levels of school engagement who are recognized as math persons don’t actually identify as one (Boaler, 2000; Catsambis, 1994). Boaler suggests
“some students have such strong academic identities and scholarly drive that they will play the school mathematics game and be successful mathematics students, but they only loan themselves to such a world, as soon as they have the chance to leave it, they do so with much relief” (p. 393). Catsambis (1994) concludes that some students are placed in higher ability groupings despite unremarkable achievement because they display the kind of engagement that schools reward. These same students consistently express more negative attitudes towards math (Catsambis, 1994).

Both Boaler (2000) and Catsambis (1994) note that this trend is particularly true for females. These findings could be useful to interrogate why many high performing students who are perceived as math people leave the STEM pipeline later in their schooling.

5.1.5 Salient findings from intra-group comparisons of MID among females.

Intra-group comparisons from the current study show that Black, Hispanic, Asian, and other race females are much more likely than their White female counterparts to express stronger-social MID. If personal math identity is interpreted as a belief that reflects personal aspirations, results from the current study are consistent with findings that showed Black and Hispanic females are least likely to aspire to math and science related careers despite reporting working harder in mathematics than their White counterparts (Catsambis, 1994).

Oakes (1990) argues that females and minorities generally receive less encouragement in math, but that when they do, they respond with interest much the same way as White males. This very well may be true for younger students; however, by the
ninth grade it appears that female students of color are more likely to disidentify from being a math person, even when others encourage them.

The current findings reinforce the theory of disidentification found in stereotype threat research. From this perspective, the findings suggest that females of color are most likely to distance themselves from a discipline where they face harmful stereotypes. While it may be the case that student expressions of MIDs are protection against a discipline where negative stereotypes endure, another interpretation can be found in the literature that deconstructs traditional mathematics pedagogy.

Research revealing that reductionist teaching strategies are most common among minority students (Anyon, 1980; Gutiérrez et al., 2011; Martin, 2003) suggests that the practices of school mathematics may appeal less to minority female students. A willingness to engage would explain why they believe others see them as math persons. Not personally identifying as a math person can be interpreted as a deliberate rejection of school mathematics practices. Studies that show that rote teaching strategies reduce student agency (Boaler, 2000) imply that MIDs is an expression of agency. From this perspective, MIDs reflects an assertion of a clash of values with school math practices. This interpretation locates the need for change within school mathematics.

From a stereotype threat perspective the findings that minority females are most likely to express MIDs represents a defensive response to implicit ability judgments about a group to which the individual belongs. From a math pedagogy perspective, MIDs can be interpreted as student expressions of determination, rejecting a discipline that has resisted culturally responsive pedagogies.
5.1.1 Salient findings from intra-group comparisons of MID among males.

Among male students, $\text{MID}_p$ increases significantly with lower SES. This trend is not observed in the corresponding study of females. These findings agree with portraits of agency of lower class males who acknowledge subordinate designations within school but interpret them from an opposing paradigm (Willis, 1977). Catsambis (1994) shows that Black and Hispanic males are likely to have strong self-assessments regarding math regardless of their measured achievement. Arguably, this observation is akin to stronger-personal MID. What Catsambis’s (1994) study does not answer is whether or not these young men acknowledge the lower status assigned to them by others. The current findings show that lower SES males are aware of how others perceive them mathematically but are more likely to reject negative evaluations. The current findings also differ from the Catsambis (1994) study by showing that race is not a significant factor when controlling for SES.

5.2 Theoretical Discussion

From Dewey’s child-centered pedagogy (1897) to Lave and Wenger’s theory of legitimate peripheral participation within communities of practice (1991), theories of learning have long sought to explain the interplay between the cognitive and social domains. Within the situated perspectives of learning, identities are not simply byproducts of participation but are constantly evolving to encourage or discourage levels of participation. The findings of the current research extend sociocultural theories to include nuanced ways an individual identifies within school mathematics as both the knower and the known (James, 1890).
In each of the populations studied, it was found that interest in mathematics increases the odds of stronger-personal MID and decreases the odds of stronger-social MID. This finding is consistent with the use of Dewey’s theory to contextualize personal identity statements. From a Deweyian framework, it was theorized that “I am” statements correspond to the amount of interest a learner has in a given activity. The results of the current study support this theoretical claim.

Foucault’s theory of hierarchical observations and normalizing judgments in systems of discipline (1977) suggests that in the context of school mathematics the “others” in “others see you” statements can be ascribed to institutionalized ability judgments. Results from the logistic regression analysis suggest that institutional ability judgments play a significant part in assigning students social math identities.

Walkerdine (1988) argues that the authoritative power assigned to these ability judgments produces the child. Others have proposed that external evaluations (e.g., grades, ability tracking, test scores) lead to a social math identity that precedes the development of personal math identity (Abreu & Cline, 2003). Abreu and Cline (2003) argue that young people first learn how they are perceived and only later decide whether to endorse or reject their social identities. The current study cannot confirm the temporality of social and personal math identity development, but it does confirm that negative institutional judgments influence stronger-personal MID. Findings support the theoretical interpretation of MID as a rejection of the negative social identities transmitted to the student, at least partially, by way of achievement measures.
Though achievement variables are significant, the current study shows that math identity formation extends far beyond an individual’s relationship to math content knowledge. Mathematics practiced as a Discourse invites identifying across multiple domains (Gee, 2003). The theory that school mathematics is a dominant Discourse that privileges dominant groups (Gee, 2003) is supported by the current findings that show significant gender, race, and SES differences in the odds of MID.

Finally, conceptualizing MID as a perspective from the “outsider within,” standpoint theory (Collins, 1986) is supported by the finding that minority female students are most likely to express stronger-social math identity dissonance. They are also the students least likely to pursue math and math-related careers (National Science Foundation, 2011). Bringing standpoint theory to bear on these findings highlights the intrinsic value of MID expressions but also cautions the researcher not to claim these findings as his own. While significant factors found to influence math identity dissonance support the theoretical construction of MID, for MID to move beyond theory, it is important to hear more from the students who experience it.

5.3 Summary

To be or not to be a math person remains in the balance for students expressing math identity dissonance. Significant differences in MID were observed that begin to shape a portrait of students more likely to express math identity dissonance. These results are by no means definitive, and many factors remain unaccounted for. The analyses of the current study are exploratory. Findings of the significance and impact of independent variables on the odds of MID expression affect future research by directing
the researcher where she might look for students who can explain the significance of MID through their own identity stories.

My findings suggest one might look for stronger math identity dissonance to be expressed by a male student of lower SES who has been placed in a lower math track and does not do particularly well on tests. It is likely that this student does not feel a strong sense of belonging in the school community and may even show up late and underprepared to class. Nonetheless, he actually looks forward to going to math class and considers it his favorite subject. He knows others do not see him as a math person, but as far as he is concerned he is. Where will this student land in his practice of mathematics?

On the other hand, current findings suggest a student expressing stronger-social math identity dissonance forms a different portrait. Perhaps this student is a Black female. She’s been placed in accelerated algebra and done well on the year end assessments. She’s might be a highly engaged student, though she doesn’t necessarily feel at home in school. She does well in math and accepts encouragement from her teacher who tells her what a natural she is. The way math is presented, however, seems entirely remote from the rest of her life, and she just doesn’t find it interesting. Furthermore, she sees very few people that she identifies with represented in math beyond school, and she knows that she is on the wrong side of an achievement gap that everyone keeps talking about. This achievement gap talk reminds her of the negative stereotypes about her group’s ability, which confirms that she is not a math person no matter what others see in her. Where will this student land in her practice of math?
Many of the current findings are consistent with previous literature. They add to that literature by offering insights into an identity struggle that has not received adequate attention in previous research. It remains unknown whether MID is a significant predictor of future math participation. The current study identifies factors that influence MID expression. It will be for future studies to determine what MID means for the students who experience it.
Chapter 6: Conclusions

6.1 Introduction

This dissertation is concerned with students who express identity conflicts related to being a math person. Specifically, I looked at a subgroup of a nationally representative sample of ninth grade students who express what I call math identity dissonance (MID). MID is expressed by opposing beliefs of how one personally identifies and how one perceives the views of others in regards to being a “math person.” To unpack the significance of MID, it was necessary to construct a theoretical framework that included contextualizing “I am” statements of personal identity, and “others see me” statements of social identity. Additionally, the term “math person” needed context in relation to U.S. culture and society, school mathematics, and student math experiences inside and outside of school. Once each of these constructs was adequately and independently theorized, I joined them into a single theory that encompasses the meaning and significance of math identity dissonance. MID is presented as a counterstory to the common measure of mathematics learning, namely math “achievement.”

While there is no single metric for achievement, the “achievement gap” is ubiquitous in school math Discourse. It evokes the stratified patterns of success rates of students defined by social groups. Throughout math research, policy, and pedagogy the achievement gap is a call to action, but the achievement gap implicitly positions marginalized students as change-worthy. Rather than focusing on disparities in measured achievement, I view mathematics learning through a lens of ongoing participation in a community of practice. Through this lens, learning is expressed through increasing
identification with mathematics Discourse. From this perspective, MID is a significant expression of struggle. MID is, in a sense, an “identification gap.” Unlike math achievement, it expresses a gulf that exists within the learner and the learner’s relation to her learning environment.

A literature review revealed that there is minimal explicit discussion of the contradictory personal and social math identities students face. I decided that to understand MID better, I needed to measure student-level variables that might influence the probability that MID is expressed. Because “achievement gap” literature and rhetoric is so ubiquitous with current math education research and policy, I decided to first view MID through common demographic factors expressed in the achievement gap literature. These included gender, race, SES, and urbanicity. To measure whether significant demographic differences change the probability that MID is expressed, I created logistic regression models that compared MID to the dummy case of not-MID in an analytic sample of over 16,000 U.S. ninth grade students. Because MID can be expressed in one of two ways, stronger-personal math identity dissonance (MID_p) and stronger-social math identity dissonance (MID_s), I created separate logistic regression models to measure each of these as the dependent variable. Because gender and math are shown in the literature to interact at the psychosocial level in significant ways, I also decided to split the sample to generate models that analyze intra-group differences for males and females.

Salient results from the quantitative analysis performed on a representative sample of ninth grade students illuminated distinct patterns of MID expression. Males were much more likely to express stronger-personal math identity dissonance and
females were much more likely to express stronger-social math identity dissonance.

There were hardly any observable race differences in stronger-personal math identity dissonance. Race, however, was robustly significant in the case of stronger-social math identity. Black, Latino/a, Asian, and students who identify as other racial minorities are much more likely to express MID_s than their White counterparts. This difference was not so evident when looking only at male students, but was extremely pronounced among female students. More than any other groups, female minority students were the most likely to express MID_s.

Probability differences attributed to SES were highly significant for stronger-personal math identity dissonance but barely evident in the case of stronger-social math identity dissonance. The analysis showed that the odds of MID_p expression dramatically increase with lower SES students. This was particularly true among male students.

To deepen an understanding of differences in MID, it was necessary to also control for prior math achievement. From the literature, one would expect a reciprocal relationship between math identity and math achievement. Stronger performance would likely lead to affirming social identities, whereas weaker performance would likely lead to negative beliefs about how one is viewed by others in the context of math. Developing an understanding of achievement through a Foucauldian lens of hierarchical observation and normalizing judgments, I theorized that resisting those judgments (both positive and negative) with an opposing personal identity is an expression of agency and struggle in ongoing math participation. In general, it was found that the odds of MID_p expression
decreased with higher traditional achievement measures. Yet math achievement was not a meaningful predictor of MID.

To better understand attitudes and beliefs that may contribute to MID, I decided to also control for students’ interest in math, beliefs about the utility of math, and self-efficacy regarding the doing of math. Each of these factors, which I referred to as math mindsets, are found in the literature as significant non-cognitive factors that affect participation and achievement, and so it seems they are salient in MID construction. I controlled for these non-cognitive factors to examine whether they influence MID in significant ways. I wanted to be able to differentiate between specific mindsets that accompany MID expressions.

A most notable finding from the analysis of math mindsets was that expressions of interest in math significantly increased the odds that they would express stronger-personal MID, i.e., identifying as a math person but believing others don’t see them as such. On the other hand, higher math interest decreased the probability that stronger-social MID would be expressed. This finding, discussed in the previous chapter, confirms Dewey’s conception of the interchangeability of personal identity and interest, which is one of the theoretical foundations of this dissertation.

I understand MID as an expression of resistance to a Discourse that I describe as school mathematics. Because I contextualized mathematics primarily within schools, I am also interested in controlling for students’ broader relationships with school. Specifically, I am interested in testing whether measures of school engagement and belonging affect the probability that MID is expressed. Because I theorize that MID is an
expression of being misunderstood in a school setting, it is important to see if this sense of dissonance is associated with weaker school belonging and engagement. From the investigation of school mindsets, a portrait of the student who identifies as a math person but believes others don’t see him that way takes on a greater form.

Stronger-personal math identity increases significantly with both weaker feelings of school belonging and weaker forms of school engagement. Those students without a strong sense of school belonging who do not necessarily feel safe and proud in their schools and who do not always adhere to the norms of school practices like coming to class prepared and on time are significantly more likely to express MID_p. On the other hand, those students who express their determination to get good grades and who are punctual and prepared for class are more likely to express MID_e. This was discovered to be particularly true for female students of color. This finding complements research dedicated to investigating factors that lead capable students away from math, factors that result in low representations of females and non-Asian minorities in math-related fields.

6.2 Limitations

This research investigates variables that influence the expression of math identity dissonance. The quantitative methods used in the study successfully identified how particular variables change the probability of MID expression. Findings from the quantitative analysis both confirm and refute hypotheses based on a review of related literature. Though several important findings were discussed in chapter 5, a number of limitations must be considered when evaluating the implications of the study and planning for future research.
For one, this study used a questionnaire to measure significant differences in the probability of MID expression. Not only does exclusive use of a questionnaire threaten to colonize students’ identities by creating the boxes that they are forced to locate themselves in, but “the expression of true opinions may be tempered by the person’s impression of what is a socially acceptable answer” (Chipman, 2005, p. 9). In the case of gender differences for example, it has been argued that highly confident expressions of mathematical ability are more socially acceptable in males than in females, whereas admissions of weakness are more socially acceptable for females (Chipman, 2005). This social conditioning imposes limits on interpreting findings such as male students are more likely to express stronger-personal MID and female students are more likely to express stronger-social MID. Though social conditioning doesn’t call into question the reliability of their expressions of MID, it does necessitate careful consideration of how these expressions may or may not mirror actual beliefs and experiences of the students in question.

Chipman’s (2005) assertion that “the questionnaires that measure these variables are fallible yardsticks” (p. 9) invites a broader discussion of the limitations of this study’s exclusive use of questionnaire data. Though the concerns expressed by Chipman can be applied to any quantitative study that relies on self-reported measures to gauge beliefs, they may be particularly relevant to this study because identity is not well defined in the questionnaire or in the literature. While it is not my intention to undermine the use of survey responses in quantitative research, it is important to look at particular challenges of the research design of this dissertation. These limitations come to light when
examining several constructs that this dissertation relied on that were captured by closed questions on the HSLS:09 student questionnaire.

To begin with, MID was operationalized based on responses to the student questionnaire, which asked students whether they agree with the statements “You see yourself as a math person” and “Others see you as a math person.” The questionnaire, however, did not define math person, nor did it pose any follow up questions to elicit from students their own meanings of math person. Furthermore, individual students were only asked whether they agree or disagree with the statements. They were not given an opportunity to indicate whether they regard the endorsement or rejection of being a math person as important to their identity. Therefore, students might agree that they are a math person on the questionnaire, but it remains unknown exactly what that means to them and whether they consider it a meaningful part of how they identify. Identity salience is important throughout the literature; unfortunately, this dissertation is limited in its understanding of the salience of the MID expressions captured.

This dissertation addresses these limitations in chapter 1 by arguing that “math person” is a culturally significant, commonly recognizable construct, with inherent value in society. Although it may be common enough to hear people use this construct to define themselves, it would be wrong to claim there is a universally agreed upon singular understanding of what is meant by math person, or that being or not being a math person is an essential aspect of a person’s identity.

Forcing students to agree or disagree with the charge of being a math person and being seen by others as a math person subordinates them to the framework of the research
design. Within the context of the survey, students were not given the freedom to dismiss this question, to ask clarifying questions, or to contextualize their response in a way that was meaningful to them. With this in mind, it’s important to be very explicit that this dissertation makes no absolute claims to students’ math identities. Rather, it is limited to a study of MID, a construct that was captured through responses to questions that students had no part in formulating and very little freedom in answering.

This acknowledgement is not meant to dismiss the study, but to call attention to how the findings within the structure of the research design are understood, beginning with the absence of a universal definition of math person. In the absence of a universal definition with which students were forced to identify or not, this dissertation constructed an understanding of math person in relation to common math practices illustrated in the literature. Though this is consistent with the theoretical framework that situates identities in practice, this dissertation is limited by the need to employ theory, rather than actual data generated from the subjects of the study, to assign general meaning and value to statements of being or not being a math person.

School mathematics, described by distinct practices and ideologies, was theorized as the dominant Discourse for situating student expressions of MID. This, however, leads to another limitation of the study. Though many practices are ubiquitous throughout school mathematics, there are a number of different types of math communities of practice where identities are enacted. Boaler and Greeno (2000) distinguished different types of mathematics classrooms (e.g., traditional versus project-based), showing that differences in pedagogy facilitated the construction of different
math identities. The current study contextualizes MID in school mathematics Discourse, but is unable to differentiate between particular kinds of classroom practices, environments, and pedagogical approaches that may be significant to MID expression. Though math mindsets that tie to school practices were measured in this dissertation, the current study is limited to analyzing how outcomes and school math mindsets, rather than pedagogy and practice, influence MID expression.

Student performance on standardized tests is an outcome variable central to a theory of MID. The current study assesses differences in the odds of MID from results from a standardized assessment of student algebra ability that was administered as part HSLS:09. Including these test scores in the set of independent variables measures how fluency with school mathematics may influence MID expression. Another way standardized tests scores are used in school is to transmit summative assessments of math ability. Test scores assign student identities ranked relative to peers, which influence the expression of MID. Unfortunately, the latter consideration cannot be assessed from the results of the current study because the students involved in the study never learned the results of the assessment included in this analysis. Therefore, interpreting the impact of test scores, a central consideration of MID formation, is limited in the current study to a discussion about fluency with school mathematics. Although it is likely that results on the algebra assessment from HSLS:09 compare to outcomes on other standardized tests that students have taken, there is no evidence to support this claim. Using test scores that were not made available to the students limits the studies ability to verify the hypothesis that standardized test rankings influence MID.
I hypothesized that measurements of math achievement are critical to whether one agrees or disagrees with the statement “others see you as a math person.” Interpreting who is implicated in “others” is a major limitation of the current study because there was no follow-up question to assess who the others may be. The questionnaire did not specify, nor did it ask students to identify to whom they are referring. Therefore, from questionnaire data alone, it is impossible to differentiate between the possible others. It is likely that given the opportunity, students would make distinctions between how they believe parents, teachers, peers, institutions, measuring tools, and other possible “others” perceive them. Distinguishing between the many others that make up a student’s school math social web would deepen an understanding of MID expression. Instead, this study is limited to treating the “other” in the abstract, as disembodied ability judgments that are manifested in the grades students receive, course tracks they are assigned, and expressions of school belonging.

The consideration of others in social math identity is limited further by using only students’ own perceptions of how others see them. To gain a fuller understanding of how the social environment mediates MID expression, it would be necessary to include the perceptions of actual others; parents, teachers, peers, and other people in the students’ life. As it stands, this research only accounts for students’ projections of an ambiguous other.

A review of related literature suggested that an expression of MID could result from a student’s different identities in in-school and out-of-school math practices. Perhaps a particular young person formed her personal math identity through the practice
of helping her parents with home finances, while her social math identity was formed through participation in a low-tracked math class. Another young person may come into his social math identity by working as a scorekeeper at a local community center but whose lack of interest in school mathematics has caused him to personally disidentify as a math person. A limitation of the current study is the impossibility of assigning specific stories to particular students, making it impossible to view the influence of outside of school mathematics practices on the expression of MID.

Sfard and Prusak (2005) argue that it is “the activity of identifying rather than its end product that is of interest to the researcher” (p. 17). In this dissertation, the activity of identifying is situated in the administration of the HSLS:09 base year student questionnaire. As a discursive practice, the questionnaire posed a number of restrictions on the stories that students were able to tell. Reliance on this data alone to operationalize a theory of MID and to investigate factors that influence its expression imposes the numerous limitations discussed in the paragraphs above.

Because there are always going to be the above sorts of limitations in a quantitative analysis that relies almost exclusively on questionnaire data, it is important to be reminded of the purpose of the current study. This study picked out salient factors from the math identity literature to include as independent variables in the logistic regression models that measure differences in the likelihood that MID is expressed. The data included in the study are based on the student questionnaire and algebra ability test of the HSLS:09 base year. However, despite 17 independent variables, the Nagelkerke $R^2$ value of the logistic models remained extremely small, accounting for a small
percentage of the variance in MID. Therefore, although this dissertation identified a number of significant variables that predict differences in MID expression, the majority of variance remains unaccounted for.

Finally, as a previously unexplored construct, there is no existing data that demonstrates MID to be an important factor in shaping persons’ actions or in determining differences in future math participation. There is always a risk in introducing a new construct as a dependent rather than an independent variable. This dissertation asked, for example, whether prior math achievement has a significant impact on the probability that MID will be expressed. The converse of the question, “does MID have an impact on future math achievement?” would be a more pressing question for many math education researchers, though.

The decision to make MID the dependent variable of this study was of course intentional. Focusing on student expressions of identity conflict in learning mathematics is meant to offer the beginnings of an alternative story to ones that view math education gaps solely through the lens of achievement. Whether or not MID is a meaningful variable for predicting pathways into or out of STEM fields remains for future studies to determine. Nonetheless, there are valuable implications of the current study that deserve consideration.

6.3 Implications

Of the number of factors that influence the probability that MID is expressed, careful consideration must be paid to groups of students under-represented in math
related fields, namely women and minorities. The current research finds that these
groups are more likely than their White male counterparts to express stronger-social math
identity dissonance. Furthermore, within group comparisons of female students show
that students of color are much more likely to express MIDs than their White female
counterparts. Although this does not provide evidence of a direct correlation between
MID$_s$ and decreases in future participation, denial of a personal math identity, despite
affirmations by others to the contrary, could feed powerful beliefs that lead students away
from mathematics.

If it is their personal identities, rather than those identities assigned to them by
others that are most at risk of leading under-represented students away from mathematics,
then interventions that focus on opportunities for these students personally to identify in
positive ways within mathematics are necessary. However, these would not be the same
interventions that are geared towards improving traditional achievement measures
because there are in fact no significant differences in achievement of those students
expressing MID$_s$. Furthermore, since increased school engagement increases the
probability that MID$_s$ is expressed, it would appear that shifts to align students to school
culture are also unnecessary interventions. Student belief in the utility of math for daily
and future lives is not a significant factor nor are student self-efficacy beliefs. It is also
not the case that parents and teachers should be the focus of interventions, as these
students already feel others recognize them as math people.

Where then does the problem lie, and who or what must change? The one
variable that decreases the probability that MID$_s$ will be expressed is students’ increased
interest in mathematics. What interventions would make students more interested in math and potentially decrease expressions of MID?

Interventions that focus on changing students can easily imply that something about their standpoints is incorrect. Alternatively, if we value the student standpoints, and see that despite normal levels of achievement, positive engagement with school and being identified by others as math people they still do not personally identify with math, then it would appear that interventions are best suited for the math itself. Instead of assigning the responsibility of change to the students, this realization considers math to be change-worthy.

The dominant Discourse of school mathematics has been resistant to change. This is not to say people have not tried. When widespread curriculum reforms have been introduced, they are mostly disregarded after several years. This was the fate of the “New Math” introduced in the 1960s, and it remains the trend today. In New York City, the largest school district in the country, four different high school curriculums have been prescribed, and three of those have been discarded, in the beginning of this century alone. This dissertation certainly does not mean to propose another publishing frenzy set off by a new curriculum. In fact, given the recent capital investment in the widespread adoption of the Common Core Learning Standards of Mathematics, it would be ludicrous to propose any dramatic shifts in the content standards of mathematics in the United States. School mathematics must change in practice.

The current research is predicated on the belief that learning equates to continued participation in communities of mathematics practice where math identities form.
Through legitimate peripheral participation in meaningful mathematics, learning should facilitate students’ identities developing along a continuum from apprentice to master. As seen through the lens of MID, however, a significant number of students experience identity conflicts. According to prominent social psychologists (e.g., Breakwell, 1983) these conflicts imply conflicting values in their practice of math. Therefore, remediating MID necessitates the realignment of values, which can be promoted through basic changes in pedagogy in school mathematics.

A recent review of interventions to alleviate stereotype threat experienced by Black students (Aronson et al., 2009) turned up an intervention that appears particularly apt to consider with the current study. The intervention alleviated stereotype threat by directing students to affirm an alternative positive identity (Cohen, Garcia, Apfel & Master, 2006). This intervention was based on a theory that through self-affirmation students have opportunities to reinforce their sense of self-worth and reduce the stress associated with stereotypes (Aronson et al., 2009; Steele, 1997). The intervention was relatively simple making it easy to replicate in non-clinical settings. Students were given a list of values (athletic ability, creativity, music, friendship, etc.) and instructed to choose their most important value from the list and write a paragraph about it that included the top two reasons the value was important to them. Following these instructions students were asked to select their level of agreement with a handful of statements regarding the value they selected. This simple intervention was shown to produce positive gains in students’ grades (Aronson et al., 2009).
In light of the success of this intervention, this dissertation proposes that math curriculum should be designed and implemented with students’ values and interests at the forefront. Interventions like the one above are not a panacea, but show the potential impact of small pedagogical modifications. In the case above, improving performance was as simple as asking students to write down their values. By inviting these values into the classroom, students experienced an identity shift. They had the opportunity to view themselves as insiders to the community of practice. While it is beyond the scope of this dissertation to offer a comprehensive proposal for curriculum reform, taking the stereotype threat intervention mentioned above one step further, could have far-reaching consequences on students’ expressions of MID.

The intervention by Cohen and colleagues (2006) was performed in an advisory class. This dissertation recommends that this intervention be extended to math classes. Student expressions of interests and values should be used to promote learner-centered school experiences. Students should see themselves and their values expressed in the mathematics that they practice. Teachers and school administrators should consider a values brainstorm at every turn in the math curriculum. If student brainstormed values were woven into the fabric of the class, appearing in content and in practice, there is a good chance that students would find their personal and social math identities converging in a positive way.

One of the reasons that research on math identities has gained so much traction in recent years is because identity can be used to predict behavior, but it is also highly malleable. Creating curricular experiences that position students as insiders of
mathematics practice, where the Discourse they engage in is saturated with their interests and values, is an important consideration for bringing marginalized students to the center.

Although arguments of cognitive inferiority were dismissed long ago, negative stereotypes that harm performance still permeate school math. Stereotype threat research recognizes the stresses associated with historically situated racist and sexist assertions of cognitive inferiority lead able students to disidentify from math (Steele, 1997). The interventions devised to alleviate stereotype threat have sought to make changes to students’ cued identities to promote academic performance (Aronson et al., 2009). The current study implies that changes must be made to mathematics itself.

The students who are most likely to express stronger-social math identity dissonance are females of color. At the intersection of numerous forms of oppression, these students offer a counterstory to dominant narratives of math achievement gaps. Denouncing themselves as math people expresses agency in the struggle against a dominant Discourse of school mathematics, which has been used over decades to assign particular groups racist and sexist identities of cognitive inferiority at the bottom of a math ability hierarchy. It is only natural that students, coming into their personal identity in adolescence, would reject these identities that explicitly marginalize them.

Years of injustice have ensured that mathematics is rigged to advantage certain groups of students at the expense of others. The so-called “achievement gap” between white students and students of color, rich students and students of lower SES, male students and female students is fundamentally about which students have the freedom to understand themselves as math people in a dominant Discourse that is slanted to favor
particular dominant groups (Gee, 2003). Viewing disparities in secondary and post-secondary math participation as a gap in math identity, not student cognitive ability, points to the necessity of adopting learner-centered, culturally responsive practices that situate students in math communities of practice that reflect their interests and values. Rather than looking to reform all of mathematics curriculum, minor changes to classroom practice could significantly increase the participation of students historically under-represented in math related majors and careers.

### 6.4 Future Research

The current study employed the base year of the High School Longitudinal Study of 2009. Future research should continue to interrogate MID expression in the base year questionnaire by including additional independent variables in the analysis. For example, it may prove fruitful to examine how teacher attitudes affect MID, or at the very least, how student beliefs about their teachers may impact MID. An analysis that includes a student’s belief that math teachers value and listen to student ideas, treat students with respect, treat every student fairly, think every student can be successful, think mistakes are okay as long as students learn, make math interesting, treat males and females differently, and make math easy to understand are all response variables in the dataset that could give a deeper understanding of MID expression in relation to student perceptions of teacher and pedagogy. Another potentially significant response item to include in future logistic models would be student responses to whether they believe males are better than females at math, females are better than males at math, or there is
no difference. Even though Nosek et al. (2002) show that many students outwardly reject stereotypes, these questions could lend valuable insights into student MID expression.

Another avenue for future base year data research is to use similar logistic models to assess more intra-group comparisons. Although I analyze male and female populations separately, a similar search for differences within particular groups, broken down by racial categories and achievement levels might illuminate salient factors for different groups. Of particular interest is whether among Black students higher achievement increases the probability that stronger-personal MID is expressed, a phenomenon McGee (2009) describes in her qualitative study of high performing Black math students in college and graduate school.

Beyond additional analyses of the base year questionnaire, the longitudinal nature of HSLS:09 will prove useful for future MID investigations. First, it will be important to determine whether MID has an impact on future math participation and performance by including performance data from the first follow up when the students are in the eleventh grade. If MID expressed in the base year proves to be a significant predictor of future participation and achievement, then it will be important to readdress many of the limitations of the current study with in-depth interviews and focus groups.

Employing a mixed-methods approach to MID research will provide a richer understanding of MID expression. In future research, it will be important to allow students an opportunity to define what is meant by “math person.” Students should have opportunities to contrast math practices from in-school experience and from outside-of-school experiences to understand how each of these informs their math identities. They
should also have opportunities to tell stories about the influence of “others.” Research should examine how parents, teachers, peers, and standardized assessment practices shape math identity dissonance.

A basic mixed methods methodology would employ surveys to identify a population that expresses MID. Following the identification of the target population, in-depth interviews should be used to form deeper insights into what MID implies from the students’ perspectives. Additionally, focus groups, combined with classroom observations where the researcher employs an identity lens to view students’ participation in practice will add to a theory of MID expression. Through a mixed methods approach, fuller portraits of students’ stories can emerge so that a deeper understanding of MID from student perspectives is formed.

Finally, any interventions conceived as a result of MID research should be rigorously studied. Math today, more than at any time in human history, informs how we live in the world. Math is the language that engineers employ to develop new technologies; scientists apply to discover cures for disease; financial brokers develop to orchestrate elaborate derivatives markets; mathematicians practice to push the limits of human understanding; and millions and millions of young people confront as the gatekeeper to many future opportunities. For some, pushing open those gates requires math experiences that resolve math identity dissonance.
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