INVESTIGATING CHANGES OF UNDERREPRESENTED STUDENTS’ MATHEMATICS IDENTITIES INTO THEIR FIRST YEAR OF COLLEGE

by

Alison S. Marzocchi

A dissertation submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Education

Spring 2015

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DEDICATION

This dissertation is dedicated to my parents, Suzanne and Michael Marzocchi. I will never be able to find adequate words to express my appreciation for the sacrifices you’ve made and the opportunities you’ve provided for me. I could never have done this without you. For your eternal support in allowing me to pursue my dreams, this dissertation belongs to you.
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ABSTRACT

This qualitative study examined factors which, according to the students, contributed to changes to or preservation of underrepresented students’ mathematics identities between their senior year of high school and completion of their freshman year of college. Specifically, the participants of this study were asked, during three one-on-one interviews, to reflect on results from a prior study in which they were participants (Marzocchi, 2013) to examine whether their mathematics identities had changed over time. The design of this study was driven by an overarching goal of examining recruitment and retention of underrepresented students in mathematics-intensive postsecondary degrees. As a means of encouraging more underrepresented students to continue postsecondary study of mathematics, I chose to focus this study on mathematics identity development. Hence, the primary research question that was addressed was What do underrepresented students report about factors that contributed to their mathematics identities after completing their first year of college, as compared to their mathematics identities at the completion of high school? To address this question, I necessarily needed to address two sub-questions: (a) How do underrepresented college freshmen describe their mathematics identities? and (b) How, if at all, did the mathematics identities of underrepresented students change between their senior year of high school and the completion of their freshman year of college?

This study is significant to the field of mathematics education for several reasons. To start, the selected participants had all developed aspects of positive
mathematics identities at the time of their senior year of high school. Accordingly, these students could serve as models for positive mathematics identity development in underrepresented students. Further, I interviewed students shortly after completion of their freshman year of college. The timing of the interviews illuminates the crucial first-year-college experience of underrepresented students. One way in which the participants expressed their positive mathematics identities in high school was through their intention to pursue mathematics-intensive college majors and careers. As of the completion of their first year of college, four participants persisted on a path to mathematics-intensive majors and three had switched to non-mathematics-intensive majors. These participants give us a range of insight into the factors that they reported as impacting their mathematics identities during the crucial first year of college.
Chapter 1

INTRODUCTION

Victor is an eighteen-year-old male who identifies himself as African American and attended public high school in a large low-income city in the mid-Atlantic region. He is social and adored by his peers and teachers and one would be hard-pressed to find him without a smile. In the classroom, Victor is attentive and pensive; he does not waste words. Victor places a high value on his peer relationships both inside and outside of the classroom. For this reason, he consciously surrounds himself with a supportive peer network and one will rarely find him alone. Tragically, statistics indicate that as an African American male who attended school in a low-income district, Victor’s chances of completing a bachelor’s degree are bleak.

Growing up, Victor always enjoyed school, particularly mathematics. Regarding his enjoyment of mathematics, he stated, “I enjoy solving things. I like to do puzzles. I like to not know something at first and then do the steps to figure out the answer. I feel good, I feel like I accomplished something.” Because of his enjoyment of mathematics, Victor participated in the Upward Bound Math/Science Program (UBMS)—a federally-funded outreach program for underrepresented students interested in mathematics and science—during three of his high school summers. He stated that he joined UBMS because, “I just figured it would be fun to go with other people who like the same thing I liked, math and science.” At one point, he even described mathematics as his “best friend.” When the time came for Victor to declare a college major, he knew mathematics would play a role in his decision, stating, “I’m interested in math and I do well in my math classes and I hope that whatever I learn I’ll be able to use in the future...in college I wanna take it and try to make a career out of it.” He decided to declare accounting as his major.

Unfortunately, Victor arrived at college and experienced mathematics difficulties right from the start. He was assigned to a developmental mathematics course, in which he received a D, and subsequently enrolled in a freshman general education mathematics course which he failed. When I met with him at the end of his freshman year, one of the
first things he told me was “I don’t like math now. I really don’t like math now.” This change had an impact on his future plans, as he was considering switching his major from accounting to criminal justice to avoid taking more college-level mathematics courses. When asked about the impact that mathematics played in his decision to change majors, he replied, “I just don’t think I want to do anything with math no more.” This decision is particularly disheartening, as just three months before starting college, Victor stated, “I’m planning on taking a math course in college beyond the minimum. I’m not trying to take the lowest possible, I want to take something challenging. I’m not just trying to just make it by.” When I met with him at the end of his freshman year, he was just trying to make it by.

What experiences did Victor have during that crucial first year of college that influenced him to change his major after feeling so confident and passionate about his decision just one year before? As a student who had seen success in high school mathematics, who had participated in an intensive summer program focusing on mathematics, and who had the passion and drive to study mathematics, shouldn’t Victor have been positioned to succeed in his mathematics courses in college? Could Victor’s college have provided better support for him so that he could see his dream through to the completion of a bachelor’s degree? Could Victor’s high school have better prepared him for the challenges of college-level mathematics? Questions such as these will be examined in this study. It is Victor, and the hundreds of other underrepresented students that I have had the privilege of working with over the past decade, that have inspired this study, and the research program surrounding it.

It is because of Victor and his peers that my research focuses on examining the recruitment and retention of underrepresented students in postsecondary mathematics. I designed this study to address this goal by following a small number of students into college who are from groups historically underrepresented in mathematics-intensive fields, who developed positive aspects of their identities toward mathematics in high school, and who were members of a college outreach program prior to college. The exploratory nature of this study will provide the field with insight into the lived experiences of underrepresented students after they transitioned from high school to
college mathematics. The experiences of these students have the potential to serve either as success stories or cautionary tales; every participant intended to pursue mathematics-intensive bachelor’s degrees before entering college, yet several switched off of this path after the completion of their first year of college. From the participants who remained on a mathematics-intensive degree path, we can learn how to foster a successful transition into college mathematics for underrepresented students. We thus learn about potential successes. From the participants who switched off of a mathematics-intensive degree path, we can acquire insight into the challenges faced by underrepresented students during their first year of college mathematics, which would be examples of cautionary tales.

A student entering college with the intention of earning a mathematics-intensive bachelor’s degree is considered, in this study, to be successful if she completes said degree. Others could conceptualize success differently. For instance, one might consider a successful student to be a student who, despite original intention, remains in college to the completion of any degree, not only a mathematics-intensive degree. Another way to conceive of success is a student who discovers and pursues a career plan that best suits herself personally. However, given that the driving rationale of this research program is to improve the recruitment and retention of underrepresented students completing mathematics-intensive bachelor’s degrees, it makes sense to define a successful student in this context as one who achieves mathematics-intensive degree completion. For the participants of this study, the recruitment aspect of the driving rationale has been achieved; now, this study is designed to investigate their retention.
I chose to focus upon underrepresented students as the participants in this study because it is important to address the inequities in mathematics education for students from underrepresented populations. Additionally, the projected population growth in the United States will be greatest among groups that are typically underrepresented in mathematics-intensive fields, yet these are fields with open positions (Curtin & Cahalan, 2004; Gandara & Bial, 2001; Tyson, Lee, Borman, & Hansen, 2007). Therefore, members of these underrepresented population groups will be called upon to pursue careers in these fields, and these fields could benefit from having a diverse population working within them. Unfortunately, it has been shown that underrepresented students struggle to develop positive academic and mathematics identities (Nasir, 2002; Polman & Miller, 2010) which could inhibit them from choosing to pursue mathematics as a field of study.

In this study, a student is considered to be underrepresented if she is low-income and/or first-generation-college. Underrepresented was conceptualized in this way because students who are low-income and first-generation-college have historically been given fewer opportunities to attain bachelor’s degrees than other population groups (Engle & Tinto, 2008). Past studies have conceptualized underrepresented differently. For instance, Moreno, Muller, Asera, Wyatt, and Epperson (1999), in their study of an intervention program targeting underrepresented college freshmen in calculus, use a definition which includes “women, Latinos, African Americans, and students from rural areas” (p. 53). Cowan Pitre and Pitre (2009), in their review of federally-funded outreach programs, define an underrepresented student to be one who identifies as a member of a non-White ethnic/racial minority group. Other authors are not as specific; Gullatt and Jan (2003),
who reviewed pre-collegiate outreach programs, define underrepresented to mean “educationally and economically disadvantaged students” (p. 6). Some choose to leave the term open; Gandara and Bial (2001), who wrote a comprehensive report on K-12 college outreach programs for underrepresented students, do not explicitly define underrepresented—they reviewed several outreach programs, each of which conceptualizes the term in its own way. Although the participants of my study are underrepresented in that they are low-income and/or first-generation-college, they are also underrepresented in other ways, as will be discussed in the Literature Review.

As a means to encourage more underrepresented students to continue postsecondary study of mathematics, I chose to focus this study on mathematics identity development. This study built upon the findings from my previous study (Marzocchi, 2013) in which I investigated the mathematics identity development of the same cohort of participants. The longitudinal nature of the data for this study afforded the unique opportunity to investigate actual changes in the mathematics identities of the participants. This investigation contributed to the exploratory nature of this study, as research on identity has rarely made use of two distinct data sets to investigate identity change. Identity was selected as the lens through which to view the students’ experiences in mathematics during their first year of college because past research indicates that students benefit from positive mathematics identity development in many ways. The benefits include a sustained interest in mathematics (Berry, Thunder, & McClain, 2011), increased engagement with mathematics (Jilk, 2014), and mathematical proficiency (Larnell, 2013). I conjectured that these benefits of fostering positive mathematics identities could help to improve the recruitment and retention of underrepresented students in postsecondary mathematics.
A model of mathematics identity that emerged from my previous study (Marzocchi, 2013) was used to capture participants’ mathematics identities. The model consists of three identity questions: *Who was I/Who am I?*, *Who do I want to be?*, and *Who can I be?* Each question is informed by several components of mathematics identity. The exploratory nature of this study served to validate this model as a valuable framework for studying mathematics identity. The model will be elaborated upon in greater detail in the Literature Review. The participants of this study could serve as models of positive mathematics identity development at the high school level, as they represent a group of exemplary, mathematically-inclined underrepresented students. They are considered to be mathematically-inclined in that they were mathematics-intending; prior to starting college they expressed an intention to pursue mathematics-intensive degrees. Further, they had received extra support in that they were former students of the Upward Bound Math/Science Program (UBMS) which focuses on college-readiness in mathematics and science. Phelan, Yu, and Davidson (1994), in their study of urban students’ school engagement, note that successful students are often omitted from the literature, yet they found that “these youth, too, experience pressures and circumstances that can adversely affect their lives in school” (p. 417). Further, because the participants of this study represent an exemplary set of underrepresented students, their struggles during the first year of college are likely the struggles of others.

The primary research question that was addressed in this study was *What do underrepresented students report about factors that contributed to their mathematics identities after completing their first year of college, as compared to their mathematics identities at the completion of high school?* To address this question, I necessarily
needed to address two sub-questions: (a) *How do underrepresented college freshmen describe their mathematics identities?* and (b) *How, if at all, did the mathematics identities of underrepresented students change between their senior year of high school and the completion of their freshman year of college?* By addressing these questions, this study contributes knowledge on how the mathematics identities of underrepresented students change or remain constant after completing their first year of college. In doing so, the study helps to address the pervasive issue of retention of underrepresented students in mathematics-intensive degree programs.
Researchers and policymakers express concern over the diminishing number of students choosing to continue their study of mathematics (Boaler & Greeno, 2000; Grootenboer & Zevenbergen, 2008; Jansen, Smith, Seeley, & Schielack, 2012; Middleton & Jansen, 2011; Treisman, 1992; Tyson et al., 2007). Tyson et al. (2007), who examined course-taking patterns across class, ethnicity, and gender, state that “the urgent need for STEM workers presents enormous challenges to our nation’s future productivity and to its educational systems” (p. 248). To address this issue, I will provide a review of the literature which rationalizes the decisions for this study’s focus on underrepresented students, on first-year college mathematics, and on mathematics identity development.

A Focus on Underrepresented Students

The shortage of qualified workers pursuing mathematics-intensive careers, coupled with the population growth among people typically underrepresented in mathematics, highlights the importance of researching the recruitment of this population into these fields. It is widely recognized that population groups such as first-generation-college students, low-income students, and some minority students (such as African American and Hispanic) are disproportionately underrepresented in college, particularly in mathematics-intensive fields (Boaler & Greeno, 2000; Colyar & Stich, 2010; Curtin & Cahalan, 2004; Engle & Tinto, 2008; Gandara & Bial, 2001;
Howard, 2003; Laguardia, 1998; Myers, Olsen, Seftor, Young, & Tuttle, 2004; Myers & Schirm, 1999; Stout, 1989; Tan & Calabrese Barton, 2012; Thayer, 2000; Treisman, 1992; Ward, 2006). Most troubling to the field of mathematics, the population growth is projected to be greatest among population groups that have historically been given the least opportunity to succeed in mathematics (Prescott & Bransberger, 2012).

Many believe that the economic well-being of the United States rests on the ability to recruit underrepresented students into mathematics-intensive fields (Curtin & Cahalan, 2004; Engle & Tinto, 2008; Gandara & Bial, 2001; Laguardia, 1998). Engle and Tinto (2008), who wrote a report examining the college experience of low-income and first-generation-college students, summarized this concern, stating:

Given the pressure to remain competitive in the global knowledge economy, it is in the shared national interest to act to increase the number of students who not only enter college, but more importantly, earn their degrees. Changing national demographics requires a refocus of efforts on improving postsecondary access and success among populations who have previously been underrepresented in higher education. (p. 1)

Further, they found that “while college access has increased for this population, the opportunity to successfully earn a college degree, especially the bachelor’s degree, has not” (p. 3). Motivating the selection of participants for my dissertation study, these authors found that students who are low-income and first-generation-college are at the greatest risk of failure in postsecondary education.

Definition of Underrepresented

For the purpose of this study, the definition of an underrepresented student is a student who is low-income and/or a potential-first-generation-college student. A low-income student is defined as belonging to a family with a taxable income of $35,775
or less for a family of four (the threshold set by the federally-funded Upward Bound program). A potential-first-generation-college student is defined as a student who is currently attending college and who does not have a parent who has earned a bachelor’s degree.

**Low-Income Students**

Studies have indicated that low-income students have been given less opportunity to attain bachelor’s degrees as compared to their higher-income peers (Engle & Tinto, 2008; Engstrom & Tinto, 2010; Thayer, 2000; Tinto, 2007). Although access to higher education has improved for low-income students, degree completion has not (Engle & Tinto, 2008; Engstrom & Tinto, 2010; Tinto, 2007). Engle and Tinto (2008) found that high-income students were six times more likely to earn a bachelor’s degree than low-income students. Shockingly, these authors found that this gap has nearly doubled over the past four decades. Even when controlling for academic ability, Thayer (2000) found that family income impacted degree completion. Jay and D’Augelli (1991), whose study examined differences between African American and White college freshmen, found on multiple occasions that students’ income had a much greater impact on their reported freshman experience than did other factors such as race. Specific to mathematics, quantitative findings have shown that low-income students, on the whole, yield lower scores on school-achievement measures than their higher-income peers (Herbers et al., 2011) and that low-income students are over-represented in the population of students who have mathematics difficulties (Jordan & Levine, 2009). These results point to low-income students having fewer opportunities in mathematics than their higher-income peers.
First-Generation-College Students

First-generation-college students are students who are attending college and whose parents do not have bachelor’s degrees. For this reason these students have the potential to feel less prepared for college than their non-first-generation peers (Bui, 2002; Cruce, Kinzie, Williams, Morelon, & Xingming, 2005; National Center for Education Statistics, 2005; Thayer, 2000). Cruce et al. (2005), who examined the relationship between perceived academic preparedness and parents’ education level, found that students whose parents earned bachelor’s degrees had a statistically higher perceived academic preparedness than students whose parents did not. The National Center for Education Statistics (2005) used postsecondary education transcript data to investigate the course-taking for first-generation-college students and found that, compared to their non-first-generation-college peers, they completed degrees at a lower rate, were more likely to be academically unprepared, earned fewer credits in their first year of college, were more likely to repeat or withdraw from courses, and had lower overall grade point averages. Specific to mathematics, they were less likely to select mathematics-intensive majors, took fewer mathematics courses (55 percent took at least one mathematics course in college compared to 81 percent for their non-first-generation-college peers), and, even among those who took mathematics courses, earned fewer mathematics credits (8 credits compared to 11 credits). A gap persisted even among mathematics majors; on average, first-generation-college mathematics majors earned grade point averages of 2.6 in mathematics compared with 3.1 for their non-first-generation-college peers.
Underrepresented in Other Ways

Although students need only to be low-income and/or potential-first-generation-college to qualify as underrepresented in mathematics in this study, these students can be underrepresented in other ways. For instance, the schools serviced by Upward Bound programs (programs which serve students who would be classified as underrepresented in this study) have an over-representation of minority students: “almost half (47 percent) of the total enrollment in [Upward Bound Math/Science] and [Upward Bound] target schools was minority; in high schools that were not Upward Bound target schools, 31 percent of enrollment was minority” (Curtin & Cahalan, 2004, p. xiii). Further,

the largest percentage (41 percent) of [Upward Bound Math/Science] participants in 2000–01 were black or African American followed by white (25 percent), Hispanic or Latino (20 percent), Asian (7 percent), American Indian or Alaska Native (4 percent), Native Hawaiian or other Pacific Islander (1 percent), and those of more than one race (2 percent). (p. xiv)

Because of the high number of minority students who would be classified as underrepresented under the conceptualization used in this study, I did not exclude research on minority students in this literature review. In other words, when searching for literature on underrepresented students, I included literature on low-income students, first-generation-college students, and minority students.

In addition to potentially being underrepresented by race, this definition of underrepresented could yield a high number of students whose first language is not English. Thus, defining underrepresented in mathematics in the way that it is defined in this study resulted in a set of participants who are underrepresented in additional ways. Lastly, although gender was not taken into account in the recruitment of
participants, several participants were considered additionally underrepresented in that they are female.

A Focus on First-Year College Mathematics

This study examined the mathematics identities of underrepresented students after they completed their first year of college. Each participant had taken at least one mathematics course during that year and hence had experienced a transition from high-school-level to college-level mathematics. In his investigation of transitions, Beach (1999) noted that much work needs to be done to determine how schools can support students experiencing transitions. The transition to college is especially important to examine as it can cause considerable difficulties for students (Appleby & Cox, 2002; Jay & D’Augelli, 1991; Tinto, 1987; Wenger, 1998), particularly underrepresented students (Engle & Tinto, 2008; Thayer, 2000). Cruce et al. (2005), who focused on the transition to college for first-generation-college students, determined that:

These students are less prepared academically for college than their peers, and that, even after controlling for academic preparation and prior academic achievement, these students are less likely than their peers to be successful in college and to persist to a degree. (p. 2)

Engle and Tinto (2008) found that “low-income, first-generation students were nearly four times more likely...to leave higher education after the first year than students who had neither of these risk factors” (p. 11). Further, the transition and retention in college-level mathematics can be especially difficult (Appleby & Cox, 2002; Engle & Tinto, 2008; Moreno et al., 1999). Engle and Tinto (2008) found that underrepresented students were equally-likely as their peers to declare science, technology, engineering, and mathematics (STEM) majors but were fifteen percent
less likely to remain in those majors. Moreno et al. (1999), who made comparisons
between different groups of students in college calculus, stated that mathematics
courses, particularly freshman calculus, “often serve as the gatekeeper to the scientific
majors and other professional majors such as business” (p. 54). Thayer (2000)
describes college mathematics similarly, describing it as “a subject that presents a
formidable barrier to continued success in college for many students” (p. 6). The
noted difficulty in college mathematics makes the transition to college-level
mathematics particularly important to study.

A Focus on Mathematics Identity Development

As a means of encouraging more underrepresented students to continue
postsecondary study of mathematics, I chose to focus this study on mathematics
identity development. I conjectured that supporting the development of students’
positive mathematics identities could help to address the problem of low
postsecondary participation in mathematics among underrepresented students (Berry
et al., 2011; Jilk, 2014). Berry et al. (2011) found that the development of a positive
mathematics identity leads to sustained interest in and persistence with mathematics.
Jilk (2014) also discussed the importance of studying mathematics identity because
“identity affects participation...students enter a practice with ideas about who they are
and their purposes for engagement” (p. 4). Once entered into that practice, in this case
the practice of college-level mathematics, students must “[reconcile] their views of
themselves and who they want to become with the identities that they are invited to
construct in the mathematics classroom” (p. 249). Unfortunately, it has been shown
that underrepresented students appear to have fewer opportunities to develop positive
academic and mathematics identities (Nasir, 2002; Polman & Miller, 2010) which
could inhibit them from choosing to pursue mathematics as a field of study. Larnell (2013), in his study of African American students’ transition to college, stated that “it is critically important that researchers broaden their conceptions of mathematical proficiency to rigorously investigate the social and psychosocial forces that impact mathematics learning” and that identity can be a “central and useful tool for analyzing the mathematics learning experiences of students and, particularly, students from groups that have experienced restricted access to mathematics” (p. 154). For these reasons, this study investigated the first-year-college experience of the participants through the lens of their mathematics identity development.

Conceptualization of Identity

The conceptualization of identity that was used in this study is depicted by a model, shown in Figure 1, which was inspired by Gholson’s (2013) questions of mathematics identity. The model captures a student’s identity by asking the questions Who was I/Who am I?, Who do I want to be?, and Who can I be? The Who was I/Who am I? aspect of a student’s mathematics identity can be addressed by assessing the degree to which a student reports that she possesses the mathematics identity components of enjoyment of mathematics, interest in mathematics, perceived usefulness of mathematics, feeling of competence in mathematics, and sense of belonging in mathematics. The Who do I want to be? aspect of a student’s mathematics identity can be addressed by assessing that student’s reported desire to continue studying mathematics and reported desire to pursue a mathematics-intensive career. Finally, the Who can I be? aspect of a student’s mathematics identity can be addressed by assessing the student’s reported belief in his/her potential to succeed in college-level mathematics, reported belief that success in mathematics is necessary for
future career success, and reported belief in the potential to succeed in a mathematics-intensive career. This model of mathematics identity emerged from my previous study (Marzocchi, 2013) and the exploratory nature of this dissertation afforded the opportunity to validate this model as a valuable framework for studying mathematics identity.

Figure 1  Model of Mathematics Identity.
Theoretical Perspective

Two theoretical perspectives on identity guided the design of this study. The first is that of the five strands of mathematics proficiency, particularly the “Productive Disposition” strand, put forth by Kilpatrick, Swafford, and Findell (2001) and the second is Wenger’s (1998) communities of practice. The mathematics identity components that were informed by each of these perspectives can be seen in Figure 2.

Kilpatrick et al. (2001) describe a productive disposition to mathematics as a “tendency to see sense in mathematics, to perceive it as both useful and worthwhile, to believe that steady effort in learning mathematics pays off, and to see oneself as an effective learner and doer of mathematics” (p. 131). Several of the components of mathematics identity conceptualized in this study were guided by Kilpatrick et al. (2001). These include a student’s level of enjoyment of mathematics, her level of interest in mathematics, the degree to which she believes mathematics is useful, and her perceived competency in mathematics. Possession of these components could lead to a desire to continue studying mathematics, a desire to pursue a mathematics-intensive career, feeling the potential to succeed in college-level mathematics, feeling the potential to succeed in a mathematics-intensive career, and believing that success in mathematics is necessary for future career success.

The second theoretical perspective that guided the design of this study was that of Wenger (1998). Wenger’s (1998) theoretical perspective conceptualizes identity as a social theory of learning, centered around our lived experience of participation in the world. Wenger’s (1998) conceptualization of identity is illustrated in the following passages:

Our identity includes our ability and our inability to shape the meanings that define our communities and our forms of belonging...Building an identity consists of negotiating the meanings of our experience of
membership in social communities. The concept of identity serves as a pivot between the social and the individual, so that each can be talked about in terms of the other. (p. 145)...Identity in practice is defined socially not merely because it is reified in a social discourse of the self and of social categories, but also because it is produced as a lived experience of participation in specific communities. (p. 151)

The inherently social aspects of learning mathematics in a college environment made it important to include Wenger’s (1998) social theory of identity in my conceptualization. Hence, the fifth and final component contributing to the Who was I/Who am I? question of mathematics identity is a student’s sense of belonging in mathematics. This component can be seen in the model of mathematics identity depicted in Figure 1. A participant could demonstrate a sense of belonging in mathematics by discussing that she felt like a contributing and/or valued member of her mathematics courses. This discussion was often associated with discussions of the participants’ feeling of competence in comparison to her peers which impacted participating in class or working collaboratively.

As detailed above, a fusion of the theoretical perspectives on identity put forth by Kilpatrick et al. (2001) and Wenger (1998) guided the research design of this study. The organization of these perspectives was guided by the questions of mathematics identity of Gholson (2013). Figure 2 is provided to show which identity components were informed by which theoretical perspective(s).

Factors Contributing to Mathematics Identity

Existing literature points to many factors which, positively or negatively, impact students’ academic and mathematics identities. These factors have been organized in Table 1. The first column in Table 1 lists the factors identified in the reviewed literature, the second column indicates whether the factor was reported to
have a positive or negative impact on students’ identities, the third column indicates (with an X) whether the factor was reported to have an impact on students’ academic identities, the fourth column indicates (also with an X) whether the factor was reported to have an impact on students’ mathematics identities, and the last column lists the citations in which that particular factor was present. The factors are listed in order from most present in the reviewed literature to least present in the reviewed literature. Only factors which were cited in at least two reviewed sources were included in the table.

**Greatest Negatively-Contributing Factor**

The factor from the reviewed literature which had the greatest negative impact on students’ identities was feeling underprepared for college-level work. Research indicates that underrepresented students are justified in feeling underprepared

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**Figure 2**  
Theoretical Perspectives Informing the Ten Components of Mathematics Identity.
<table>
<thead>
<tr>
<th>Factor</th>
<th>Impact (pos/neg/both)</th>
<th>Impacts Academic Identity</th>
<th>Impacts Math Identity</th>
<th>Citations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feeling underprepared for college-level work</td>
<td>negative</td>
<td>X</td>
<td>X</td>
<td>Engstrom &amp; Tinto, 2010; Moore et al., 2010; Nasir, 2002; National Center for Education Statistics, 2005; Thayer, 2000; Tinto, 2007; Tinto, 1987; Treisman, 1992; Tyson et al., 2007; Walsh, 2010</td>
</tr>
<tr>
<td>Involvement in collaborative learning</td>
<td>positive</td>
<td>X</td>
<td>X</td>
<td>Engstrom &amp; Tinto, 2010; Powell &amp; Berry, 2007; Tinto, 1987; Treisman, 1992; Walker, 2006</td>
</tr>
<tr>
<td>Participation in college support programs</td>
<td>positive</td>
<td>X</td>
<td>X</td>
<td>Engle &amp; Tinto, 2008; Engstrom &amp; Tinto, 2010; Moreno et al., 1999; Morning, 2012; Tinto, 1987</td>
</tr>
<tr>
<td>Perceiving the college learning environment as supportive</td>
<td>positive</td>
<td>X</td>
<td>X</td>
<td>Engstrom &amp; Tinto, 2010; Moreno et al., 1999; Person, 2012; Tinto, 1987</td>
</tr>
<tr>
<td>Misalignment between home culture and college culture</td>
<td>negative</td>
<td>X</td>
<td></td>
<td>Phelan, Yu, &amp; Davidson, 1994; Thayer, 2000; Tinto, 1987</td>
</tr>
<tr>
<td>Having direct access to faculty</td>
<td>positive</td>
<td>X</td>
<td>X</td>
<td>Person, 2012; Powell &amp; Berry, 2007; Tinto, 2007</td>
</tr>
<tr>
<td>Different nature of college math compared to high school</td>
<td>both</td>
<td>X</td>
<td></td>
<td>Jilk, 2014; Moreno et al., 1999</td>
</tr>
</tbody>
</table>
(Engstrom & Tinto, 2010; Moore et al., 2010; Nasir, 2002; National Center for Education Statistics, 2005; Thayer, 2000; Tinto, 2007; Tinto, 1987; Treisman, 1992; Tyson et al., 2007; Walsh, 2010). In his study of minority student performance in college-level calculus, Treisman (1992) indicated that “minority students often enter the university with fewer credit hours of science and mathematics from high school and with substantially lower SAT scores” (p. 364) which could indicate that they have been given less opportunity to succeed in college mathematics than their White counterparts. In a large-scale study of college readiness in students across Texas, Moore et al. (2010) discovered that:

White students…had the highest percentage of college-ready graduates in math, followed by Hispanic students…The lowest percentage of college-ready graduates in math was for African American students…White students had more than twice the percentage of college-ready graduates in math than did African American students…and almost 50% more college-ready graduates in math as did Hispanic students. (p. 829)

Tyson et al. (2007), who examined course-taking patterns across class, ethnicity, and gender, found that:

Black and Hispanic students complete lower level high school courses, but Black and Hispanic students who did take high-level courses are as likely as White students to pursue STEM degrees. Findings suggest that…racial disparities occur because fewer Black and Hispanic students are prepared for STEM in high school. (p. 243)

I conjecture that this pattern of lower-level mathematics course taking among underrepresented students could be attributed to several factors including inequities in schools’ tracking procedures, fewer higher-level courses being offered (as was the case for the participants of this study), or decreased likelihood to opt into higher-level courses due to influences of negative mathematics identities or lowered sense of belonging in mathematics. Once an underprepared underrepresented student enters a
college-level mathematics course and sees her mathematics preparation in comparison to the preparation of her better-prepared peers, her mathematics identity may be negatively impacted. As Tinto (1987) explains:

Academic difficulty...reflects a situation in which the demands of the academic system prove too great. The individual either doesn’t have the ability to meet those demands or has yet to develop and apply those skills and study habits needed to do so. (p. 116)

Due to the disproportionately high number of underrepresented students who are underprepared for college-level mathematics, it is not surprising that this was the leading negatively-contributing factor cited in the reviewed literature.

**Greatest Positively-Contributing Factor**

The factor from the reviewed literature which had the greatest positive impact on students’ identities was an involvement in collaborative learning (Engstrom & Tinto, 2010; Tinto, 1987; Treisman, 1992; Walker, 2006). Treisman (1992) found, in his widely-cited study, that whether or not minority students were succeeding in college-level calculus was linked to whether or not they were working collaboratively with their peers outside of class. Walker (2006) conducted a study in which high achieving mathematics students in a predominantly minority school were identified by teachers and peers. Supported by interview data, many of these successful mathematics students had a supportive peer group and/or a friend who they would work with in mathematics. Walker observed that “many of these high-achieving students were committed to helping others and approaching each other for help if they themselves were having problems” (p. 60). Students in Engstrom and Tinto’s (2010) study reported benefitting from working collaboratively as it helped them to “feel less alone, more confident in their ability to succeed in college, and more supported in
their studies” (p. 48). These feelings that students experience when working collaboratively can contribute to positively supporting their identities.

Summary

Given the demographics of the participants of this study, a review of the literature led me to conjecture that several participants would have experienced some difficulty in transitioning to college-level mathematics. The literature indicated that many students, particularly underrepresented students, feel underprepared for college-level work. I conjectured that the feeling of under-preparation could negatively impact the participants’ mathematics identities in the following ways: decreased enjoyment of mathematics, decreased interest in mathematics, decreased feeling of competence in mathematics, and decreased sense of belonging in mathematics. The decrease in these components of the Who am I? question of mathematics identity could then cause participants to change their view of Who can I be? by causing them to question their potential to succeed in college-level mathematics and in a mathematics-intensive career. I further conjectured that this change would result in a subset of the participants rethinking Who do I want to be? and choosing to change their major and career plan. This conjecture was supported by the literature indicating that underrepresented students are more likely to switch out of mathematics-intensive majors than their non-underrepresented peers.

On a positive note, the literature indicated that working collaboratively in mathematics has a positive impact on participants’ mathematics identities. At the time of conducting the literature review, I was uncertain as to how this finding would manifest in the set of participants for this study. Results from my previous study (Marzocchi, 2013), at the end of the participants’ senior year of high school, indicated
that the participants rarely worked collaboratively in mathematics. I did not know whether the participants would continue the practice of working on mathematics in isolation, or whether the college environment, or the high demands of college mathematics classes, would foster collaboration. Regardless of knowing whether this set of participants would participate in collaborative learning in college-level mathematics, I conjectured that the mathematics identities would be positively supported for the participants who chose to work collaboratively. In particular, I believed that collaboration would positively support their enjoyment of mathematics, feeling of competence in mathematics, and sense of belonging in mathematics which, in turn, could contribute to encouraging participants to persist in their mathematics-intensive majors.
Chapter 3

METHODS

This exploratory qualitative study built upon findings from a previous study (Marzocchi, 2013) to uncover factors which contributed to changes, if any, to the participants’ mathematics identities between their senior year of high school and completion of their freshman year of college, according to participants’ self-report. Specifically, the participants of this study were asked to reflect on results from my prior study (Marzocchi, 2013) about their identities as reported a year prior, when they were in twelfth grade, to determine whether their mathematics identities had changed over time, the ways in which they changed (if changes occurred), and factors that contributed to any changes, from their perspectives. The use of longitudinal data contributed to the exploratory nature of this study, as it is uncommon for research on identity to investigate change by making use of data sets from two distinctly different time points, one before a transition and one after. The subsections that follow will describe the participants, data collection, and data analysis.

Participants

The participants for this study were seven mathematically-inclined underrepresented college freshmen from a predominantly low-income city in a mid-Atlantic state. The students all participated in my previous study (Marzocchi, 2013) and consented to participate in this second study. At the time of data collection, the participants had recently completed their freshman year of college (see Table 2 for
demographic information and Table 3 for school information on each participant). The participants were considered to be mathematically-inclined in that they were mathematics-intending (in the prior study, they all reported the intention to pursue mathematics-intensive college degrees) and in that they had received additional support in mathematics that their peers may not have received (they had all completed the requirements of a mathematics- and science-focused college outreach program). All participants were former students of the federally-funded Upward Bound Math/Science Program (UBMS). Their program site was a small, public liberal arts college located outside of a major mid-Atlantic city.

As the participants of this study were UBMS students, they met the eligibility requirements of Upward Bound in that they were low-income\(^1\) and/or potential-first-generation-college-students. Specifically, four of the participants were both low-income and first-generation-college (Hope, Naida, Ruckshana, & Victor), two participants were low-income only (Isabella & Wanika), and one participant was first-generation-college only (Timothy). This information is also included in Table 2.

Being low-income and/or first-generation-college classifies the participants as underrepresented in mathematics, as defined in this study, but several of the participants were underrepresented in other ways. For instance, five of the participants (Hope, Isabella, Naida, Ruckshana, & Wanika) were female, two participants spoke a first language other than English (both Hope and Isabella first spoke Spanish), five participants did not speak English at home (Hope, Isabella, 

\(^1\) UBMS changes the qualification for low-income status yearly. The definition in 2012, at the time of participant recruitment, was $35,775 or less for a family of four. Current information can be found at [http://www2.ed.gov/about/offices/list/ope/trio/incomelevels.html](http://www2.ed.gov/about/offices/list/ope/trio/incomelevels.html).
Table 2 Description of Participants.

<table>
<thead>
<tr>
<th>Pseudonym</th>
<th>Gender</th>
<th>Race/Ethnicity*</th>
<th>Birth Country*</th>
<th>First Language*</th>
<th>Low Income?</th>
<th>First Generation?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hope</td>
<td>Female</td>
<td>Latina/Hispanic</td>
<td>Dominican Republic</td>
<td>Spanish</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Isabella</td>
<td>Female</td>
<td>Hispanic</td>
<td>Dominican Republic</td>
<td>Spanish</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Naida</td>
<td>Female</td>
<td>Hispanic</td>
<td>USA</td>
<td>English &amp; Spanish</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Ruckshana</td>
<td>Female</td>
<td>Bengali-American</td>
<td>USA</td>
<td>English &amp; Bengali</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Timothy</td>
<td>Male</td>
<td>Hispanic/Dominican</td>
<td>USA</td>
<td>English &amp; Spanish</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Victor</td>
<td>Male</td>
<td>African American</td>
<td>USA</td>
<td>English</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Wanika</td>
<td>Female</td>
<td>African American</td>
<td>USA</td>
<td>English</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

*Race/ethnicity, birth country, and first language were self-reported by participants
### Table 3  
Participants’ Schools.

<table>
<thead>
<tr>
<th>Pseudonym</th>
<th>High School*</th>
<th>College*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hope</td>
<td>South Street High School</td>
<td>Suburban Public College</td>
</tr>
<tr>
<td>Isabella</td>
<td>South Street High School</td>
<td>Suburban Public College</td>
</tr>
<tr>
<td>Naida</td>
<td>South Street High School</td>
<td>Mid-Size Teaching University</td>
</tr>
<tr>
<td>Ruckshana</td>
<td>North Ridge Park High School</td>
<td>Large Research University</td>
</tr>
<tr>
<td>Timothy</td>
<td>Sunny Hill High School</td>
<td>Large Research University</td>
</tr>
<tr>
<td>Victor</td>
<td>South Street High School</td>
<td>Small Liberal Arts College</td>
</tr>
<tr>
<td>Wanika</td>
<td>Sunny Hill High School</td>
<td>Large Research University</td>
</tr>
</tbody>
</table>

*School names are pseudonyms.

Naida, Ruckshana, & Timothy), four participants self-identified as Hispanic (Hope, Isabella, Naida, & Timothy), and two participants self-identified as African American (Victor & Wanika). The subsections that follow will provide the reader with a brief introduction to each participant by sharing salient aspects of each participant’s mathematics identity, past mathematics experiences, and/or experiences in college mathematics.

**Hope**

Hope’s personality can best be described as bubbly. She always has a smile on her face and her love for life is apparent. She is highly intelligent and passionate about learning; she truly enjoys learning for learning’s sake and one can noticeably see
her face light up when she makes a new discovery. Hope self-identifies as Hispanic and is both low-income and potential-first-generation-college. She was born in the Dominican Republic and Spanish was her first language, as well as the language she speaks at home. Hope’s family has generally remained uninvolved with her college education. Their lack of involvement has caused some stress for her because they do not understand the workload in college and they often pressure her to take her attention away from her college work for family social obligations. Hope has always felt high competence in mathematics, has enjoyed it, has found it to be interesting, and has found it to be useful. Of all the participants, her mathematics identity was classified as being the most positive in high school and this continued into college.

Hope attends Suburban Public College where she majors in biology with the intention of becoming a medical doctor or a researcher. She first discovered her passion for scientific research during her final summer in UBMS when she was chosen for a special research internship with a college professor (funded through a privately-funded nonprofit organization in her home state). In her thirteen years of schooling, this research experience was her first time in a science lab. She immediately fell in love with the work and was inspired to select biology as her major.

Isabella

Isabella is impressively mature for her age. She is goal-focused and she rarely, if ever, strays from her path. She sets a very high standard for herself and she works to her full potential to meet this standard. At times, her high expectations for herself are a source of stress, but she is reflective and recognizes that this stress is a necessary obstacle on the path to her goals. She avoids many social distractions in college and chooses instead to maintain loyal and supportive relationships with a select few
friends. Isabella is low-income and self-identifies as Hispanic. She was born in the Dominican Republic and Spanish was her first language, as well as the language she speaks at home.

Isabella attends Suburban Public College where she majors in mathematics education with the goal of becoming a high school mathematics teacher. She found her passion for teaching as a child when she would play school with her younger sister (pretending to be a teacher and student). Growing up, she discovered her talent for teaching mathematics when she would help her peers with their homework. Although Isabella enjoyed mathematics in high school, and continued to in college, she experienced a decrease in her feeling of competence in mathematics. She attributed this change to her experience in discrete mathematics, where the content was unlike any mathematics she had seen in the past. She also felt less prepared for discrete mathematics as compared to her peers.

Isabella has a sister who is one year older and also attends Suburban Public College. Her sister is a biology/premedical major and is an essential source of support for Isabella. She and her sister are good friends and are similar in their work ethic.

Naida

Naida is an amazingly empathetic young woman; she is an advocate for social justice and has a keen eye for seeing inequity. She is always questioning the state of the world and is constantly reevaluating the role she can play in fixing injustices. Naida identifies herself as Hispanic and is both low-income and potential-first-generation-college. Spanish is the language spoken in her home. As a potential first-generation-college student, Naida imposes great pressure on herself. She feels an
obligation to pave the way for her future family members and consequently believes that failure in college is not an option.

On the whole, Naida has felt disconnected from school mathematics. She perceived her high school courses as being too easy for her and this often caused her to disengage. At Mid-Size Teaching University, Naida completed a lab-based general education mathematics course. The students were expected to work on computer modules at their own pace without any professor interaction. Naida found this format to be painfully uninteresting. After this experience, Naida never wanted to take a math course again so she changed her major from business to law. Not surprisingly, she plans to use her law degree to advocate for marginalized population groups.

Ruckshana

Ruckshana is poised and well-spoken. She prides herself in being a strong and progressive woman. She is highly intelligent but lazy at times; she knows she is smart enough to complete a college degree which sometimes causes laziness and unnecessary difficulty. She self-identifies as Bengali-American and is both low-income and potential-first-generation-college. She does not speak English at home. Ruckshana has found support in several older cousins who have completed mathematics-intensive college degrees. Her cousins are a major source of information and encouragement.

Ruckshana has always enjoyed mathematics, and continues to in college. The more she studies, the more she sees the usefulness of mathematics. She continues to make stronger connections between her science courses, her mathematics courses, and her life. She attends Large Research University where she majors in biomedical engineering. Although Ruckshana has not faltered on her path to her engineering
degree, she experienced a decrease in her feeling of competence in mathematics; once believing herself to be a top student in mathematics, Ruckshana now sees herself in comparison to her better-prepared peers. She finds herself working harder than she has ever needed to work in mathematics. Interestingly, Ruckshana was the only participant who seemed to be aware of inequities in the education system before beginning college (perhaps being made aware by her older cousins); she went into college expecting that she would be underprepared, but she did not know how this would have an impact on her experience until she actually got there.

Timothy

Timothy is somehow friendly and shy at the same time. His shyness is endearing and one cannot resist describing him as a teddy bear. People are naturally attracted to him and he has many friends, but his social life has interfered with his school work, at times. Timothy knows that he has not made the best decisions in college, but he believes that life is full of learning experiences. He allows himself to make mistakes so long as he can learn from them and grow. He is potential-first-generation-college, self-identifies as Hispanic, and speaks Spanish at home. He has a very supportive family including two older siblings who did not succeed in higher education. Timothy has gained wisdom from his siblings’ mistakes. Many of his family members, including those siblings, encourage him on his path to degree attainment.

Timothy attends Large Research University where he majors in biology with the intention of becoming a veterinarian. He has encountered obstacles on his path, namely failing precalculus twice. The failures have impacted his feeling of
competence in mathematics. Despite this change, Timothy believes he can complete the degree and he has already started researching graduate veterinary programs.

Victor

Recall that Victor was featured in the opening vignette of this dissertation. Readers are encouraged to revisit this vignette to reacquaint themselves with Victor.

Wanika

Wanika is a compassionate, creative, and individualistic young woman. She is aware that she does not fit the mold of a typical person her age but she always remains true to herself. Perhaps for this reason, she states that she loves animals more than people. Wanika is low-income and self-identifies as African American. Her identification as African American impacts her feeling of competence and sense of belonging in mathematics. She noted that there were not many other African American students in her mathematics courses and she stated a belief that African Americans do not “click” in this area. Wanika’s mother is very involved in her education but in many ways this has been discouraging. Her mother puts great pressure on her to pass her mathematics courses, yet constantly reminds her of her mathematics difficulties.

Wanika has never enjoyed mathematics, has never found it interesting, and has never found it useful. She is an interesting case because she is the only participant who had a low feeling of competence in mathematics before starting college. She felt that she had never demonstrated mastery of mathematics material in school, yet she passed all of her K-12 mathematics courses. She claims that she never understood, and still does not understand, mathematics. Wanika attends Large Research
University where she was originally a biology major with the intention of becoming a veterinarian. After experiencing many difficulties in college mathematics, including failing precalculus twice, Wanika switched her major to animal science (a less-mathematics-intensive major) and dropped the veterinarian plan.

Data Collection

The data sources for this study were three one-on-one interviews between myself and each of the seven participants, for a total of 21 interviews. The interviews were face-to-face and audio-recorded and each lasted between 30 and 75 minutes. The interviews took place after the participants had completed their first year of college. The model of mathematics identity (see Figure 1) that guided this study was used to inform the interview protocols. Additional data sources included the participants’ high school and college transcripts.

Interviews were an appropriate data collection approach to address the research questions because they allowed the participants to describe their current mathematics identities, describe how they changed since their senior year of high school, and attribute any changes to factors that they experienced during their freshman year of college. The interactive nature of an interview allowed me to ask clarifying questions and to solicit more detail, when necessary. This interaction helped me to gain a better understanding of the participants’ mathematics identities and the factors contributing to changes in their identities, according to the participants. Specific interview questions were guided by the two primary theoretical perspectives of identity that influenced this study: Wenger’s (1998) conceptualization of identity as a social construction and Kilpatrick, Swafford, and Findell’s (2001) conception of the “productive disposition” strand of mathematical proficiency. Questions were written
to purposefully address the components of mathematics identity illustrated in the model of mathematics identity that guided this study (see Figure 1). Details on each interview will be found in the subsections that follow.

I chose to use student self-report data to capture students’ identity changes from their perspectives. The use of student self-report data contributed to the exploratory nature of this study, as it allowed the participants to share their experiences from their perspectives, and afforded them the opportunity to speak of a variety of aspects of their mathematics identities. The decision to use student self-report data was motivated by past researchers who have made use of self-report data when studying identity (e.g. Berry et al., 2011; Howard, 2003; Sfard & Prusak, 2005). Berry’s line of research on successful African American students’ mathematics identities (e.g. Berry et al., 2011; Powell & Berry, 2007) supports giving underrepresented students a voice in the literature. Consequently, his studies make use of interviews and mathematics autobiographies. Howard’s (2003) study also gives voice to underrepresented students, particularly African American students. He explained:

little research has explicitly addressed African American students' own perspectives of their college ambitions and the manner in which they construct their college potential and academic identities. (p. 5)...As marginalized students continue to struggle with finding their place in schools, it is imperative that future research take into account students' viewpoints. (p. 14)

He stated that it is important to provide “a space for African American high school students to contribute to this important dialogue about their own perspectives and opinions on their prospects for college, the formation of their academic identities, and their educational experiences in general” (p. 4) and that such research is “inexplicably
absent from the discourse” (p. 4). Although only two out of my seven participants identify as African American, I believe that it is important for members of a variety of underrepresented population groups to have a voice in the mathematics identity literature. The subsections that follow will provide greater detail on the nature of each of the interviews conducted in this study.

First Interview

The first interview was a structured interview broken into five smaller parts (see Appendix A for the interview protocol). Part A consisted of introductory questions about college in general. Part B made use of previous data by presenting each participant with a copy of a personalized narrative that was constructed following data collection for my previous study (Marzocchi, 2013). After the first interview of my prior study, I typed a narrative for each participant summarizing what I had learned about her mathematics identity, changes to her mathematics identity, and factors contributing to those changes. At the start of the second interview of my prior study, the participant was given the opportunity to revise her narrative. Therefore, the revised narrative reflects information on the participant’s mathematics identity during her senior year of high school, as approved by the participant herself (see Appendix B for a sample narrative). The bulk of Part B of this interview asked the participant to reflect on how she has changed since the narrative, and factors contributing to any changes. The use of the narrative from my previous study afforded the unique opportunity to investigate identity change and how factors experienced during the first year of college contributed to any changes. During Part C, the participant’s current college major plans and future career plans were discussed. If these plans changed since high school, reasons for any changes were also discussed. Part D of the
interview explicitly discussed the participant’s underrepresented status and asked the participant to reflect on whether she perceived that her underrepresented status had an impact on her experience with college mathematics. Part E consisted of closing questions.

Second Interview

The second interview was also a structured interview broken into five smaller parts (see Appendix A for the interview protocol). Part A asked the participant whether she had thought of anything she would like to tell me since our last interview. Part B of the interview examined the participant’s college transcript class-by-class and discussed all college-level mathematics courses. Part C discussed experiences outside of college mathematics classrooms that may have influenced the participant’s mathematics identity. In Part D, we discussed the role of UBMS on the participant’s mathematics identity. This discussion was saved for the end of the interview to see if the participant would already spontaneously discuss the program without being prompted to do so. Whether or not the participant mentioned UBMS during prior parts of the interview, the role of UBMS was discussed in Part D. Part E consisted of closing questions.

Third Interview

After transcribing and conducting a preliminary analysis of the first two interviews, I constructed an individualized protocol for each participant’s third interview. The third interview protocol was personalized for each participant because it was developed based on the participant’s responses during the first two interviews (see Appendix A for sample interview questions). Despite individual differences in
the protocols, the overarching purpose of the third interview was to seek clarity on any lingering questions after a preliminary analysis of the first two interviews and to systematically address themes that emerged following the first two interviews.

Data Analysis

Data for this study consisted of three transcribed interviews with each participant, participants’ high school transcripts, and participants’ college transcripts. The alignment of the data sources and analytic methods with particular research questions guiding this study is organized in Table 4. All coding was done using NVivo software. The analysis was conducted using two sets of codes; the first set of codes contained the ten components of mathematics identity (see Figure 1) and the second set of codes consisted of factors potentially contributing to participants’ mathematics identities. The first stage of analysis consisted of examining the two sets of codes separately.

The mathematics identity component codes were analyzed using a typological analysis (Hatch, 2002; Lofland, Snow, Anderson, & Lofland, 2006; Weiss, 1995). This type of analysis was followed because the typologies—the ten mathematics identity components from my prior study (Marzocchi, 2013)—had been predetermined. I coded the transcripts for all occurrences of the participants’ discussing each identity component and I used the coding sheets generated by NVivo to search for patterns and themes within and across typologies.

The analysis conducted on the contributing factor codes primarily resembled an inductive analysis (Hatch, 2002; Lofland et al., 1995). This stage of the analysis

2 NVivo qualitative data analysis software; QSR International Pty Ltd. Version 9, 2010.
was not purely inductive, as a number of the codes had been predetermined from the literature or from my prior study (Marzocchi, 2013), but it was primarily inductive in that “the analysis is driven by the data themselves” (Lofland et al., 1995, p. 195). Additionally, the predetermined codes were only included in this study if they were validated by the data and any unmentioned codes were dropped. Interview transcripts were coded using a combination of the predetermined codes and new codes that emerged from these data. Each time a participant spoke of a factor which was not in the current set of codes, a new code was added. The result was a comprehensive list of codes to capture the factors which the participants spoke of as contributing to their mathematics identities. The identification of contributing factors that were not

<table>
<thead>
<tr>
<th>Sub-question A</th>
<th>Question</th>
<th>Primary Data Sources</th>
<th>Analytic Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>How do underrepresented college freshmen describe their mathematics identities?</td>
<td>Interview 1, Part B, Discussion of narrative</td>
<td>I followed a typological analysis to code the transcribed interview data for any time a participant spoke of one of the 10 components of mathematics identity. Each of the 10 components was assigned a code so that all instances of a participant speaking of their mathematics identity were captured under that code.</td>
</tr>
</tbody>
</table>
Sub-question B
How, if at all, did the mathematics identities of underrepresented students change between their senior year of high school and the completion of their freshman year of college?

Interview 1, Part B, Discussion of narrative
Data from Marzocchi (2013)

Research Question
What do underrepresented students report about factors that contributed to their mathematics identities after completing their first year of college, as compared to their mathematics identities at the completion of high school?

Interview 1, Part B, Discussion of narrative
Interview 1, Part C, Major/career plans
Interview 1, Part D, Underrepresented status
Interview 2, Part B, College math courses
Interview 2, Part C, Other college experiences
Interview 3, Personalized questions

I followed an inductive analysis to code the transcribed interview data for any time a participant spoke of a factor experienced during the first year of college. I used two NVivo features, proximity search and matrix coding, to link factors to identity components.

revealed in previous literature contributed to the exploratory nature of this study. At the conclusion of coding, I again used the coding sheets generated by NVivo to search for patterns and themes within and across codes.

Lastly, an inductive analysis (Hatch, 2002; Lofland et al., 1995) was conducted to link the two separate sets of coded data. This analysis sought to determine how particular factors were related to particular identity components. In doing so,
particular factors could be linked to changes in identity that were experienced during the transition from high school to college mathematics. This analysis was unique in that few studies of identity have investigated change. For this analysis, I made use of two features of NVivo: proximity search and matrix coding. The proximity search allowed me to determine when a participant was speaking of a contributing factor alongside mention of an identity component. Matrix coding unveiled sections of a transcript that were double-coded for both a factor and an identity component. Additionally, I constructed analytic memos to track themes that emerged as I conducted these analyses.

**Statement of Positionality**

In this subsection, I will share my standpoint that led me to pursue this line of research. I hope to make my values and experiences explicit so that I may reveal any potential biases in this work. The path begins with my educational history: Although I did not grow up in a high-income household, my parents were impressively strategic with the money that they had and I was privileged to attend school in a high-income district. The district was a top-ranked district in a state often commended for its education system. Although I appreciate all of the opportunities that I was afforded by attending school in this district, and I attribute many of my successes in life to my exceptional K-12 preparation, this school experience left me completely ignorant of inequities in our education system. I assumed that all students were having the same experience and were given the same opportunities as I was given (I had no means of knowing otherwise!) and therefore students who were not achieving at the same level as me had only themselves to blame. I naively believed that one’s successes in life
were purely a result of one’s hard work and intelligence. In my mind, there were no other contributing factors.

It was not until the summer of 2004 (the summer after my sophomore year of college), when I first started working for the Upward Bound Math/Science Program as a mathematics tutor and counselor, that I was made aware of inequities in our education system. It was here that I encountered some of the smartest and hardest working students of my career. Yet, despite being so intelligent and hard-working, I was horrified to discover the number of students reading and writing below middle-school level or the number of students unable to solve basic mathematics problems. I was further shocked to learn that the valedictorians were only scoring 500s on the mathematics section of the SAT—an average student in my district would easily score in the 600s\(^3\). How could this be? It shattered everything I thought I knew about opportunity and success. That first summer working for UBMS was the single timeframe that had the greatest impact on the rest of my life. I was sickened by the failure of our school system to adequately prepare some of our most promising and intelligent citizens for full participation in society. These were the students who should be leading and innovating not struggling and being marginalized. In that summer, I found my life’s work.

I cannot enter this line of research free from bias, as I strongly believe in ameliorating the inequities in our education system. However, I do not believe that this bias is detrimental; even if one is somehow able to ignore these issues from an equity perspective, there are mountains of data that indicate the pertinent need to

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\(^3\) And of course, as a product of my educational environment, I believed the SAT to be a flawless measure of one’s intelligence at that time.
address this issue (e.g. Boaler & Greeno, 2000; Colyar & Stich, 2010; Curtin & Cahalan, 2004; Engle & Tinto, 2008; Gandara & Bial, 2001; Howard, 2003; Laguardia, 1998; Myers et al., 2004; Myers and Schirm, 1999; Stout, 1989; Tan & Calabrese Barton, 2012; Thayer, 2000; Treisman, 1992; Tyson et al. 2007; Ward, 2006). Not only do I conduct research in this area but, to this day, I continue to spend my summers working for the same UBMS program that so drastically changed my life over a decade ago.

That being said, when reading this study it is important to consider my unique position of being both the principal investigator of this study and an administrator and teacher at the participants’ former UBMS site. My role at UBMS allowed me to build considerable rapport with my participants; I had the pleasure of teaching each participant in at least one course and I lived in dormitories with the participants for all three of their UBMS summers. I had known the participants for four years at the time of data collection. I believe that my position can be viewed as a positive contribution to this study. For one, the rapport I had built with the participants may have helped to encourage them to participate in the study. Secondly, my relationship with each participant provided me with a deeper understanding of their mathematics identities, an understanding that I may not have been able to obtain through a series of interviews alone. Further, the pre-established rapport may have resulted in richer findings as I conjecture that the participants already trusted me and were willing to open up to me about their experiences.

**Trustworthiness**

Throughout the analysis, I was certain to implement strategies to support the trustworthiness of the qualitative data analysis. LeCompte (2000) reminds qualitative
researchers that trustworthiness starts with the study design. The study should be “based on clearly articulated theories” (p. 152) and should be tightly aligned to the research questions. Howe and Eisenhart (1999) agree, stating that “the data collection techniques employed ought to fit, be suitable for answering, and the research question entertained” (p. 6). In this study, the research questions guided the data collection and analysis techniques, as I maintained alignment to the driving theories and research questions throughout the process. Table 4 summarizes the alignment between the research questions, data sources, and analysis techniques. The first chapter of my results addresses both of my sub research questions and will present findings on the participants’ mathematics identities and how they reported that their identities changed since high school. The set of codes that started the analysis of this chapter was both theoretically and empirically based; the codes, subsequent analysis, and presentation of the results were driven by the model of mathematics identity (depicted in Figure 1) which emerged from the literature and was validated empirically by my previous study (Marzocchi, 2013). The second chapter of the results addresses my primary research question by discussing the factors which contributed to participants’ mathematics identities. Again, the set of codes that began the analysis of this chapter was both theoretically and empirically based; an initial set of codes emerged both from the literature and also from findings of my previous study (Marzocchi, 2013). As recommended by LeCompte (2000) and Howe and Eisenhart (1999), the design of the analysis for this study was driven by the research questions and the implementation of the analysis was grounded theoretically and empirically.

In addition to maintaining fidelity to the research questions and guiding theories, I also implemented specific validity-checking moves. Creswell and Miller
(2000) recommend that researchers first identify their lens and theoretical perspective before determining appropriate validity-checking moves. I determined that I was serving as my own lens—because I did not employ external reviewers such as auditors or the participants themselves—and that my theoretical perspective was constructivist—because I believe in “pluralistic, interpretive, open-ended, and contextualized (e.g., sensitive to place and situation) perspectives” (Creswell & Miller, 2000, p. 125). Using my own lens and taking a constructivist perspective dictates that the recommended validity procedure is to search for disconfirming evidence (Creswell & Miller, 2000; Howe & Eisenhart, 1999). Searching for disconfirming evidence is a “process where investigators first establish the preliminary themes or categories in a study and then search through the data for evidence that is consistent with or disconfirms these themes” (Creswell & Miller, 2000, p. 126). Throughout the analysis, I searched for disconfirming evidence to my hypotheses and I discounted hypotheses that were disproven. As an example, I believed I could claim that the participants who were members of college support programs had better study skills than the participants who were not members of such programs. I searched for disconfirming evidence and found that there was evidence present of both members and non-members having poor study skills. This claim was deemed invalid. Searching for disconfirming evidence for the claims I was making reinforced the trustworthiness of the findings presented in this study.

Another validity-checking move that I implemented in this study was to use mild member-checking techniques. Member-checking consists of “taking data and interpretations back to the participants in the study so that they can confirm the credibility of the information and narrative account” (Creswell & Miller, 2000, p.
Member checking was done in the third interview when participants were asked to reflect on emerging themes from the first two interviews. For instance, after conducting the first two rounds of interviews, I was beginning to suspect that the college-support-program members were experiencing many advantages over the non-members. I used the flexible protocol of the third interview to include questions for the college support members designed to determine whether they perceived that they were experiencing advantages. Example of such questions were “The last time we met, you spoke a lot about your experiences with the college support program. Can you talk to me about what you think are the benefits of being a member in that program?” and “What do your friends who are non-members think about the program?” Member-checking questions such as these that were asked during the third interview helped to test the validity of emerging themes.

Another way in which I validated the findings was in instances when the participants were reporting on opportunities available in their institutions. When possible, I consulted with the institutions to confirm that the participants’ reports were accurate. For example, when several of the participants reported that they did not have the same opportunity as their more affluent college peers to take high-level high school mathematics courses, I contacted guidance counselors from the participants’ school district. The counselors confirmed the participants’ report of course offerings. It should be noted that in all instances when I consulted institutions to verify participants’ report, the participants’ report was found to be accurate.

Lastly, I used the validity-checking technique of rich description which “enables readers to make decisions about the applicability of the findings to other settings or similar contexts” (Creswell & Miller, 2000, p. 129). In the presentation of my
results, I strive to provide substantial evidence to support my claims, as well as reporting on the participants who did or did not experience what I am reporting on. My goal was to provide the reader with enough evidence to be able to make judgments about the generalizability of the claims I am making. Rich description and the other validity-checking moves implemented in this study serve to support the trustworthiness of the results.
Chapter 4

RESULTS CHAPTER I: MATHEMATICS IDENTITY CHANGE AND STABILITY

The results of this study will be presented in two chapters. This first chapter will share results on the changes to and stability of the participants’ mathematics identities from the end of their twelfth grade in high school to the end of their first year in college, as reported by the participants. This approach is unique, as few studies of identity have reported on change from one distinct time point to another. The second chapter will share results on the factors experienced during the first year of college which impacted the mathematics identities of the participants, from their perspectives. In other words, this chapter will address the sub-research questions of (a) How do underrepresented college freshmen describe their mathematics identities? and (b) How, if at all, did the mathematics identities of underrepresented students change between their senior year of high school and the completion of their freshman year of college? while the next chapter will address the primary research question of What do underrepresented students report about factors that contributed to their mathematics identities after completing their first year of college, as compared to their mathematics identities at the completion of high school?.
Who was I/Who am I?

Enjoyment of Mathematics, Interest in Mathematics, and Perceived Usefulness of Mathematics

Recall that the Who was I/Who am I? question of mathematics identity is addressed by five components: enjoyment of mathematics, interest in mathematics, perceived usefulness of mathematics, feeling of competence in mathematics, and sense of belonging in mathematics. On the whole, the participants did not report substantial changes in their enjoyment of mathematics, interest in mathematics, and belief that mathematics is useful. In general, those components remained stable between senior year of high school and freshman year of college.

Majority of the participants did not discuss substantial shifts in their enjoyment of mathematics between high school and college. Four participants reported that they generally enjoyed mathematics in high school and continued to enjoy mathematics in college (Hope, Isabella, Ruckshana, & Timothy) and two participants reported that they generally did not enjoy mathematics in high school and this continued in college (Naida & Wanika). Victor was the exception to this trend. He reported that he enjoyed mathematics before college; last year he stated, “I enjoy solving things. I like to do puzzles. I like to not know something at first and then do the steps to figure out the answer. I feel good, I feel like I accomplished something.” However, he reported that he no longer enjoyed mathematics in college, stating:

I don’t like math now. I really don’t like math now. The math I took it was totally different than math I ever took because it started out with numbers and then by the fourth week it was no more numbers no more it was just letters and symbols and weird stuff. I wasn’t used to it. There was no more just multiplication. It was taking symbols, you gotta memorize certain symbols and what they mean. So I was like nah I gotta step away from math right now.
A similar trend was seen for the participants’ interest in mathematics. Two participants who reported an interest in mathematics in high school continued to find it interesting in college (Hope & Timothy). The two who reported that they did not find it interesting in high school reported that they did not find it interesting in college (Naida & Wanika). The reader should note that Isabella and Ruckshana did not discuss their interest in mathematics in this study. Methodologically, when the participants were asked to reflect on changes to their mathematics identities from high school, they did so by revisiting the narrative that they co-constructed in my previous study (see the First Interview subsection of the Methods section). Isabella’s narrative did not discuss her interest in mathematics, hence it was not reflected upon in her discussion of identity changes in this study. Ruckshana’s narrative only discussed her interest in mathematics through her intention to pursue a mathematics-intensive degree. Her narrative did not discuss her general interest in mathematics as a subject. Hence, similar to Isabella, she did not reflect upon changes in her interest in mathematics in this study.

Regarding changes to the interest in mathematics component, Victor was again the exception. In high school he stated, “I’m interested in math and I do well in my math classes and I hope that whatever I learn I’ll be able to use in the future.” He reported losing this interest in college, stating, “It seems boring to me now.” Lastly, the participants’ perceived usefulness of mathematics followed a similar trend. Hope, Isabella, and Timothy reported seeing mathematics as useful in high school and continued to report this in college. The same was true for Ruckshana, however Ruckshana’s perceived usefulness of mathematics was greatly reinforced in college. She spoke extensively, in all three interviews, about how much she was seeing the
connections between mathematics and science. These connections reinforced her belief in the usefulness of mathematics. The following excerpt exemplifies how she spoke about this:

That’s something that I noted...about how math is useful...I definitely figured that out [in college]. Even in chemistry and physics I realized how math is everywhere...there’s just so much math everywhere, I feel like there’s numbers everywhere. One time I found myself just randomly thinking like a physics person. I’m walking and I see this girl she’s walking into the door and I think to myself oh my gosh I need to catch up to her and I’m thinking how come I can catch up to her, I’m so far away from her, oh because I’m accelerating and I’m like what am I thinking about [laughs]. So definitely physics opened my mind a lot about a lot of those stuffs too. So it’s not just in calculus or something where you need math, you need math in almost any class. So that was something that I realized during college. I definitely still believe that [math is useful].

Similar to the previously mentioned identity components, Naida and Wanika reported that they did not see much use for mathematics in high school and they continued to report this belief in college. Once again, Victor was the exception. In high school, he reported a belief that mathematics is useful, stating:

Yeah I think math is useful. Cuz you need math every day. I never understood when teachers said that you need math and then when I got older I realized you do need math every day...to figure out certain stuff real fast, you need to pay your bill or something. You need to figure out how much money you put down to save to pay for that bill coming up. Math is really useful.

In college, he still reported believing that financial mathematics is useful, but he reported that he did not see the usefulness of college mathematics in his own life:

I didn’t think it was useful for me. I didn’t get it no more. I think the basic math, like learn how to multiply and divide and learn how to budget, when it comes to money it’s useful because if you spend your money not wisely, you’ll be broke. So I think it’s useful, that part, but when it comes to like the symbols, it’s only useful if you’re gonna be an engineer or something but for me it’s not useful that part.
On the whole, with Victor being the exception, these three components did not contribute substantial changes to the *Who am I?* question of mathematics identity.

**Feeling of Competence in Mathematics**

Unlike the previously mentioned components, the feeling of competence in mathematics component had a strong negative impact on the *Who am I?* question of mathematics identity, according to the participants. Across the board, this component saw the greatest negative change of any component with five of the seven participants (Isabella, Naida, Ruckshana, Timothy, & Victor) reporting a decrease in their feeling of competence in mathematics. These changes are summarized in Table 5. The reader should note that the methods of this study did not capture the magnitude of these changes (for instance, a small change versus a large change). Instead, I use Table 5 to report summaries of the change, to give the reader a sense of the similarities and differences between high school and college for the participants.

Five participants reported experiencing a decreased feeling of competence between their senior year of high school and completion of their first year of college. Ruckshana was one such participant; at the end of her senior year of high school, Ruckshana was confident in mathematics, believing that she was “better than average.” She stated, “I’m pretty good at math. I have a good confidence in math, better than average...I have done well in my math classes.” After completing a year of college, she reported that she no longer believes she is naturally talented in mathematics. She explained, “I realize how hard I have to work at it...that was something I realized, I’m more of the hard worker than the talented one in math.” Victor shared a similar experience. In high school he believed that mathematics came easy to him and it was a subject for which he did not need to study. He explained,
Table 5  Summary of Changes in Feeling of Competence.

<table>
<thead>
<tr>
<th>Pseudonym</th>
<th>2013 Findings (high school)</th>
<th>2014 Findings (college)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isabella</td>
<td>Her confidence jumped around but she always did well in math. Her highest grades were in math.</td>
<td>She felt surprised and unprepared by the difficulty of college math, particularly discrete math.</td>
</tr>
<tr>
<td>Naida</td>
<td>She felt so ahead of her peers that she would sleep in math class. She felt that she was “advanced.”</td>
<td>She no longer feels ahead of her peers. She believes math comes more easily to her peers.</td>
</tr>
<tr>
<td>Ruckshana</td>
<td>She was confident in math. She believed she was better than average. She did not need to study in math.</td>
<td>She now thinks that she is more of a hard worker than naturally talented in math.</td>
</tr>
<tr>
<td>Timothy</td>
<td>He felt confident in math. He felt ahead of his peers in math.</td>
<td>He failed precalculus twice. He no longer feels ahead of his peers.</td>
</tr>
<tr>
<td>Victor</td>
<td>Math came easy to him. He did not need to study in math.</td>
<td>He experienced several low grades in college math which decreased his feeling of competence.</td>
</tr>
</tbody>
</table>

“[Math] is so easy, I don't know why. It just came to me fast. I didn't even need to study hard like most people. I could just look at it and I could tell the answer...I've been successful in math.” During his first year of college, Victor experienced a few low grades in mathematics—he received a D in a developmental mathematics course and an F in a freshman-level general education mathematics course—which decreased his feeling of competence. He stated, “I didn’t need to get that low of a grade. When I got to college, math made me feel dumb. It made me feel like I didn’t learn nothing.” Ruckshana and Victor were representative of many of the participants in that their reported feeling of competence in mathematics decreased as a result of
feeling unprepared for college-level mathematics. A decreased feeling of competence in mathematics had a negative impact on the Who am I? question of mathematics identity which, in turn, negatively impacted the Who do I want to be? and Who can I be? questions. This component alone had the greatest reported negative impact on the participants’ path to mathematics-intensive college degrees.

Sense of Belonging in Mathematics

In high school, all seven participants reported feeling a sense of belonging in mathematics, particularly among their peers in the college outreach program. In college, there was variety among the participants in whether they reported a sense of belonging in their college-level mathematics courses. Their reported sense of belonging in college-level mathematics was most often linked to their feeling of competence in mathematics as compared to their perceived competence of their peers. When participants perceived that they had a similar level of competence in mathematics as their peers, they reported feeling a sense of belonging in that mathematics course (Hope, Isabella, & Victor). For instance, Victor perceived that in one of his college-level mathematics courses all of the students were struggling with the material. He stated, “I felt that I belonged because everybody in that class was struggling and everybody was asking for help and everybody was always there when [the professor offered tutoring]. So I felt like I belonged.” The participants’ sense of belonging was positively supported when they perceived that they has a similar level of competence to their peers. On the other hand, when participants perceived that their level of competence in mathematics was different from their peers, they reported that they did not feel a sense of belonging in that mathematics course (Isabella, Naida, Victor, & Wanika). Notably, this trend occurred both when participants felt more
competent than their peers (Isabella) and when they felt less competent (Naida, Victor, & Wanika). For instance, when asked about her sense of belonging in college mathematics, Wanika, who did not feel competent in either of her college-level mathematics courses, stated:

No, I felt like the dumbest person in that class. I felt like I was the only person not getting it, I was the only person getting Ds...In intermediate algebra I was the same way I was like what’s wrong I’m the only person in the class not getting this and I felt like everybody was looking at me like you got that wrong, you’re so dumb.

Isabella also reported that she did not feel a sense of belonging in one of her college-level mathematics courses but, in Isabella’s case, she felt that she did not belong because she perceived herself to be more competent than her peers. When asked about her feeling of competence in that particular course, she responded:

Not as much because the people who were in my class, they didn’t like math so it used to take them longer to get it. When I was done with my tests I didn’t want to hand it in because I’m like oh my god I’m going to be the first one. So I felt like I was a little bit above.

Whether the participants perceived themselves to be more or less competent compared to their peers, they reported that their sense of belonging was negatively impacted by perceiving that they were not on the same level.

The results from this study led me to conjecture that the participants reported feeling a sense of belonging in their high school college outreach courses because they perceived themselves to be of similar competence to their outreach peers. This conjecture is logical, as the participants of the outreach program all attended high school in the same district and all met the same requirements for admission to the program. In college, with students coming from a variety of educational backgrounds,
this is not the case and, consequently, the participants’ sense of belonging in their college mathematics courses was impacted.

**Who do I want to be? and Who can I be?**

The *Who do I want to be?* question of mathematics identity is addressed by the desire to continue studying mathematics and desire to pursue a mathematics-intensive career components. These components were intertwined with the feeling the potential to succeed in college-level mathematics and feeling the potential to succeed in a mathematics-intensive career components which contribute to the *Who can I be?* question of mathematics identity. At the start of their freshman year of college, all seven participants intended to pursue mathematics-intensive college majors and careers. Four participants persisted on this path (Hope, Isabella, Ruckshana, & Timothy), while the remaining three did not (Naida, Victor, & Wanika).

**Switching off of a Mathematics-Intensive Career Path**

After completing a year of college, three participants decided to change their major (Naida, Victor, & Wanika) and career plan. All three of these participants switched from a mathematics-intensive to a non-mathematics-intensive major. These changes are highlighted in Table 6.

In all three cases, mathematics reportedly played a role in their decision to switch majors. When asked for reasons behind their decision, the participants responded in the following ways:

Naida: As a business student I would have to take macro and micro economics and that involves math and I hate that, it’s so hard.
<table>
<thead>
<tr>
<th>Pseudonym</th>
<th>2013 Findings (high school)</th>
<th>2014 Findings (college)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naida</td>
<td>Deciding between business and neuroscience</td>
<td>Switched to law</td>
</tr>
<tr>
<td>Victor</td>
<td>Deciding between accounting or criminal justice, with a preference for accounting</td>
<td>Leaning towards criminal justice over accounting</td>
</tr>
<tr>
<td>Wanika</td>
<td>Planned to major in biology with the intention of becoming a veterinarian</td>
<td>Switched to animal science and dropped the plan of becoming a veterinarian</td>
</tr>
</tbody>
</table>

Victor: I know for accounting I have to take math so right now accounting is losing to criminal justice. I might do criminal justice because I think I just need to take a gen ed math so right now I’d be done with math. I know for accounting I gotta take more math classes in the future.

Wanika: My goal of becoming a veterinarian changed because I looked at it and it’s really hard and I want to be realistic with myself because I’m not that good in math...Being a veterinarian requires a lot of money, a lot of time, and a lot of math. I don’t have the patience for all that math and I already know that I won’t be able to do future math courses because I’m just not good at it...It’s a big factor.

Recall that the participants of this study were selected because they represent mathematically-inclined underrepresented students. For that reason, it is particularly disappointing that mathematics was a key factor in their decision to switch majors.

Seeing Success in Mathematics as Necessary for Future Success

Regarding the seeing success in mathematics as necessary for future success component, all seven participants spoke of at least one of their mathematics courses as
a requirement that needed to be filled, rather than as a course of importance or interest in its own right. Mathematics courses were frequently spoken of as obstacles that needed to be overcome, or courses that needed to be checked off of a list, so that the participants could move on to other courses of interest. College mathematics courses were spoken of in this way more often than they were spoken of as courses of interest in their own right; the participants did not express a genuine interest in learning the material in these courses nor did they report seeing a link between the course material and their own lives and future plans. The following excerpts from each participant illustrate this finding:

Hope [when asked if her intermediate algebra course had an impact on her belief in the usefulness of mathematics]: I don’t know, it was neutral. I felt like the whole time I was there I was like I’m doing it because I just have to take it, not because I wanted to.

Isabella: I was just taking the class [precalculus] because I had to take it and not because I wanted to.

Naida [when asked if her intermediate algebra course had an impact on her interest in mathematics]: No it was just a class I had to take and that’s it...it’s just something I have to do to reach whatever I want...I had to pass this class because I had to take it...I’m not going to act like I enjoyed this class.

Ruckshana: I don’t hate math in the sense where I don’t ever want to do it, it’s more like I just need to get through it...I didn’t really have any strong feelings about precalc. It was more of just a class I had to pass and move on...I guess I was happy I was done with it, I was like I’m done finally I don’t have to deal with it anymore.

Timothy: [Mathematics courses] are things that I need to get out of the way before I can take my real classes...I just want to get rid of that class [precalculus] so I can move on.

Victor [when asked if he believed his math for the modern world course was important for his future success]: I think just passing the class is important for the future, but the material, for this class, no.
Wanika: [In college] you’re just doing the work because you have to not because you want to enjoy it...I don’t want to take math classes in college but I have to. I have one more, I’m counting down my math classes, so I have one more precalc class to take and then that’s it...It’s a hurdle...It’s just a huge pain for me. It’s a huge test from the world to pass it so I can get to my other level classes because you can’t do anything without precalc. I can’t do certain classes I can’t register for this class, it’s holding me back.

It was surprising that every participant described at least one of their mathematics courses in this way because I assumed that this group of students, who participated in a mathematics program in high school and who chose mathematics-intensive majors in college, would be engaged with their mathematics coursework. When mathematics is viewed as nothing more than an obstacle, it is unlikely that the courses will have a positive impact on students’ mathematics identities. In sum, approximately half of the participants showed stability in the Who do I want to be? and Who can I be? questions of their mathematics identity, while the remaining participants reported changes to their future plans and their belief in their own potential in mathematics.

**Summary**

A summary of the changes to and stability of the Who was I/Who am I? question of the participants’ mathematics identities is provided in Table 7. It summarizes the results for each participant for each component. The reader should note that I do not share how the sense of belonging in mathematics component changed for each participant between high school and college. This is because the participants’ sense of belonging often varied in different settings (between a college-outreach setting and a traditional classroom setting in high school or between one college-level course and a different college-level course in college) which left me unable to make solid claims about how their sense of belonging changed in the
Table 7  Summary of Changes to and Stability of Who was I/Who am I?.

<table>
<thead>
<tr>
<th></th>
<th>Enjoyment</th>
<th>Interest</th>
<th>Usefulness</th>
<th>Feeling of Competence</th>
<th>Sense of Belonging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hope</td>
<td>no substantial change (always enjoyed)</td>
<td>no substantial change (always interested)</td>
<td>no substantial change (always found useful)</td>
<td>no substantial change (always felt competent)</td>
<td>felt a sense of belonging</td>
</tr>
<tr>
<td>Isabella</td>
<td>no substantial change (always enjoyed)</td>
<td>[did not discuss]⁴</td>
<td>no substantial change (always found useful)</td>
<td>decrease in feeling of competence</td>
<td>varied</td>
</tr>
<tr>
<td>Naida</td>
<td>no substantial change (never enjoyed)</td>
<td>no substantial change (never interested)</td>
<td>no substantial change (never found useful)</td>
<td>decrease in feeling of competence</td>
<td>did not feel a sense of belonging</td>
</tr>
<tr>
<td>Ruckshana</td>
<td>no substantial change (always enjoyed)</td>
<td>[did not discuss]⁴</td>
<td>increase in perceived usefulness</td>
<td>decrease in feeling of competence</td>
<td>varied</td>
</tr>
<tr>
<td>Timothy</td>
<td>no substantial change (always enjoyed)</td>
<td>no substantial change (always interested)</td>
<td>no substantial change (always found useful)</td>
<td>decrease in feeling of competence</td>
<td>did not feel a sense of belonging</td>
</tr>
<tr>
<td>Victor</td>
<td>decrease in enjoyment</td>
<td>decrease in interest</td>
<td>decrease in perceived usefulness</td>
<td>decrease in feeling of competence</td>
<td>varied</td>
</tr>
<tr>
<td>Wanika</td>
<td>no substantial change (never enjoyed)</td>
<td>no substantial change (never interested)</td>
<td>no substantial change (never found useful)</td>
<td>no substantial change (never felt competent)</td>
<td>did not feel a sense of belonging</td>
</tr>
</tbody>
</table>

⁴ Isabella and Ruckshana did not discuss their interest in mathematics in this study. See the Enjoyment of Mathematics, Interest in Mathematics, and Perceived Usefulness of Mathematics subsection of this chapter for a methodological explanation for this.
transition from high school to college. Instead, I summarize their sense of belonging in college mathematics, without comparing this to their sense of belonging in high school. Readers should also note that the intent of this table is to provide a brief overview of these changes, to be consulted as a reference. It is not comprehensive. Thus, readers should be mindful of the oversimplification of the results in the presentation of this table. Consider the table to be a simplified summary of the results which were elaborated upon throughout this chapter.

Regarding *Who do I want to be?* and *Who can I be?*, four participants persisted on their mathematics-intensive career paths while three did not. The three participants who changed majors all switched from a mathematics-intensive major to a non-intensive one and all cited their college mathematics courses as playing a key role in their decision to switch. The participants all spoke of at least one of their college-level mathematics courses as a course that they were taking out of obligation and not out of actual interest in the material.
Chapter 5

RESULTS CHAPTER II: FACTORS CONTRIBUTING TO MATHEMATICS
IDENTITY

In the previous chapter, the reader learned of the ways in which components of
the participants’ mathematics identities changed or remained stable between their
senior year of high school and completion of their freshman year of college, according
to participants’ self-reports. This chapter will provide detail on the factors which the
participants reported as contributing to their mathematics identities. When relevant,
these factors will be linked to changes in identity components. This approach is
unique to this study, as the longitudinal nature of the data allowed for the
determination of changes in identity. This chapter serves to address the primary
research question What do underrepresented students report about factors that
contributed to their mathematics identities after completing their first year of college,
as compared to their mathematics identities at the completion of high school?.

An overview of the factors that the participants reported as contributing to their
mathematics identities is provided in Table 8. The first column lists the contributing
factors, the second column indicates the number of participants who reported that each
factor impacted their mathematics identities, and the final columns indicate (with an
X) whether the factor was discussed as having a positive contribution or a negative
contribution (or both) to the participants’ mathematics identities. The intention of
indicating whether a factor had a positive or negative contribution is to give the reader
a sweeping sense of the impact of each contributing factor. Readers are cautioned that
this is an oversimplification of the results. The contributing factors interacted with the components of mathematics identity in nuanced ways, as is elaborated upon throughout this chapter. Table 8 only intends to provide an overarching summary of the factors and their contribution, for the purpose of orienting the reader.

Table 8  Factors Contributing to Mathematics Identity, as Reported by Participants.

<table>
<thead>
<tr>
<th>Factors</th>
<th>Number of participants</th>
<th>Reported influence on math identity</th>
</tr>
</thead>
<tbody>
<tr>
<td>High school to college comparison factors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Believing that high school study skills are inadequate for success in college mathematics</td>
<td>5</td>
<td>X</td>
</tr>
<tr>
<td>Feeling unskilled in graphing calculator usage</td>
<td>3</td>
<td>X</td>
</tr>
<tr>
<td>Feeling less prepared for college-level mathematics as compared to their peers</td>
<td>7</td>
<td>X</td>
</tr>
<tr>
<td>Factors pertaining to the mathematics professor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feeling encouraged to (or discouraged from) participating in class</td>
<td>3</td>
<td>X</td>
</tr>
<tr>
<td>Perceiving that the professor is willing and available to help</td>
<td>3</td>
<td>X</td>
</tr>
<tr>
<td>Perceived quality of the professor</td>
<td>7</td>
<td>X</td>
</tr>
<tr>
<td>Outside-of-class support factors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Working collaboratively with peers</td>
<td>5</td>
<td>X</td>
</tr>
<tr>
<td>Seeking opportunities for help or tutoring</td>
<td>5</td>
<td>X</td>
</tr>
<tr>
<td>Feeling supported by an advisor or role model</td>
<td>5</td>
<td>X</td>
</tr>
<tr>
<td>Participating in a college support program</td>
<td>5</td>
<td>X</td>
</tr>
<tr>
<td>Factors outside of the college</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family involvement</td>
<td>6</td>
<td>X</td>
</tr>
</tbody>
</table>
The contributing factors are organized into four categories: high school to college comparison factors, factors pertaining to the mathematics professor, outside-of-class support factors, and factors outside of the college. These factors will be elaborated upon in the following subsections. A fifth subsection, Impact of the Underrepresented Status of the Participants, is also included in this chapter. The participants’ underrepresented status did, at times, have an impact on their mathematics identities. This impact will be elaborated upon in the final subsection of this chapter.

**High School to College Comparison Factors**

The high school to college comparison factors include believing that high school study skills are inadequate for success in college mathematics, feeling unskilled in graphing calculator usage, and feeling less prepared for college-level mathematics as compared to their peers. I conjecture that these factors were uncovered in this study because of the unique investigation of identity changes. The investigation of change allowed participants to compare their experience in high school mathematics to their experience in college. In doing so, we gain important knowledge on how the participants’ experiences in high school impacted their mathematics identities in college. Unfortunately, each of these factors contributed negatively to the mathematics identities of the participants who reported experiencing them. The factors will be discussed in greater detail in the following subsections.

**Study Skills**

All of the students who experienced a decrease in their feeling of competence in mathematics (Isabella, Naida, Ruckshana, Timothy, & Victor) reported a need to
change their study habits between high school and college. They reported that the study skills required for success in their high school mathematics courses were inadequate for success in college mathematics. Given that such a high proportion of the participants in this study discussed their inadequate study skills, I was surprised that this finding did not reveal itself in the reviewed literature. Several past studies spoke of ill-preparation generally (e.g. National Center for Education Statistics, 2005; Thayer, 2000) but did not specifically discuss study skills. In this study, several participants discussed the difference between their study habits in college as compared to high school:

Isabella: It’s a completely new experience, becoming independent, doing stuff on my own, these classes are completely different from what I took in high school. In college, if you don’t find help, no one is going to help you. You have to seek help. So I think it was a new experience and I learned to become independent, learning new study habits and stuff. In high school I did study and do my homework but not as much as now. Basically all the time I’m doing math or reading or doing a paper. It’s nonstop basically.

Ruckshana: High school you can put a little amount of effort and you would still pass the class because it’s easier so you think of yourself as the person who already knows everything. It wasn’t so hard, things were more given, everything was in your notebook...my teacher would give me problems that were going to be on the exam and then I would just study those problems and I would pass the exam. Obviously in college it’s not like that.

Victor: In high school you’ll get away with little mistakes. In college if you don’t do it the right way you’re just going to fail. College is more strict than high school was in the math classes...Nobody should fail [in high school] because it’s nothing compared to college. You don’t really need to do a lot [in high school]. You just go there and listen and then do the homework. Compared to college certain teachers just throw it at you.
Recall that these participants were the top students in their high school, particularly in mathematics and science. In high school, they believed that being good at mathematics meant that they did not need to do much studying.

After reflecting back on their high school mathematics experiences in comparison to the experiences they were having in college, they reported that their high school mathematics courses did not equip them with the skills they would need to study in college. Ruckshana explained, “Going to [my high school] you don’t have those study habits that suburban schools have...It’s sad to say but it’s true. We’re more scared going into college because we don’t have those study habits. We’re just figuring out our study habits.” Isabella felt similarly, stating, “In high school I didn’t study as much, I was like OK I get this, look over my notes, and I’d do fine on the test. College is different, if you don’t study you fail basically. And I had no ways of knowing how to study.” Fortunately, all of the participants who experienced a decrease in their feeling of competence in mathematics reported that they acquired new study habits. Ideally, these new study habits will leave them better prepared for their future mathematics courses.

Graphing Calculator Usage

Three participants (Isabella, Ruckshana, & Victor) reported that using a graphing calculator was a source of difficulty for them in college mathematics. This factor was also not present in the reviewed literature. Although only three participants spoke of their graphing calculator usage, the calculator had a substantial impact for these three. They stated:

Isabella: I don’t like graphing as much...It was only the graphing part of [my mathematics course] that I didn’t feel prepared for.
Ruckshana: There were the calculator problems and the non-calculator problems and I sucked on the calculator problems for some reason. On the graphing it was so weird and I hated the calculator problems so that’s what really brought down my grade. I had a little bit of experience with the calculator before, it was intro stuff it’s not like I had the full knowledge of how to do it.

Victor: With the calculator, I had to memorize a lot of formulas. And it had to be three parenthesis and the right symbols and stuff and I was bad at the calculator. The first exam I did bad on because the calculator messed me up...certain equations need to be put in the calculator a certain way. If you miss one parenthesis the whole problem is wrong...That’s really important in college. If you miss that one parenthesis the whole problem is wrong.

I conjectured that these calculator difficulties could be attributed to the limited access to graphing calculators in a low-income school district. After making this conjecture, I collected follow-up data from each participant on their graphing calculator usage in high school and found that they all had a similar experience; the teachers of certain courses (typically geometry and precalculus) had a classroom set of graphing calculators that they would allow students to use for a select few lessons throughout the school year. The students did not possess their own calculators, nor were they able to bring the classroom calculators home. Each participant had contact with a graphing calculator for fewer than 20 mathematics lessons throughout their entire high school career. Their experience is in contrast to anecdotal evidence that I experienced as a student in a high-income district, where every student in the school was required to purchase their own calculator, and as a teacher in a middle-income district, where the school distributed calculators to each student and collected them back at the end of the year. In both of my experiences, the calculators were fluently integrated into the curriculum. Thus, I conjecture that the participants of this study were taking college
mathematics courses alongside peers who, on the whole, were arriving at college with far more graphing calculator experience.

From the way the participants discussed their graphing calculator usage in their college mathematics courses, I am left with a sense that their college mathematics professors expected that graphing calculator fluency was a prerequisite skill for college mathematics courses. As underrepresented students from a low-income high school district, these participants were not given the opportunity to build that fluency. They reported that their grades in their college mathematics courses suffered as a result.

Feeling Unprepared for College-Level Mathematics

All seven participants reported that they felt unprepared for college-level mathematics. This finding aligns with much past literature discussing the ill-preparedness of underrepresented students in college and in college-level mathematics (e.g. Engstrom & Tinto, 2010; Moore et al., 2010; Nasir, 2002; National Center for Education Statistics, 2005; Thayer, 2000; Tinto, 2007; Tinto, 1987; Treisman, 1992; Tyson et al., 2007; Walsh, 2010). The results of this study revealed that there was an apparent gap between the high school expectations and the college expectations in mathematics for these participants. To discuss this finding, Naida and Wanika were selected as student cases because they both spoke of feeling unprepared for college generally, as well as feeling unprepared for mathematics specifically. Regarding under-preparation for college in general, Naida stated:

You go into college saying I’m not going to quit, I’m going to do this. But when you’re confronted with it, it’s a different story. I always have that thought like why am I doing this, what’s the point of doing this, we come from this bad area and then we have to go over there, compete,
and you can’t even compete because you’re not even at the other people’s level. I was in class and all these people know all these things and I’m like I don’t think I belong here because I don’t know any of it. At those times, I was discouraged to stop.

Specific to mathematics, when learning about the trigonometry concept of the unit circle, she reflected:

You think you know stuff and then you get to college and you don’t know anything. I feel like some of my professors expect you to know things...and everyone will raise their hand and I’m almost the only one not raising my hand because we didn’t really do that in high school. There were times like that but I really try not to think about it because obviously I can’t complain that I come from this place because that’s no excuse. I acknowledge it, I know it, but I try not to focus on that.

Naida spoke on several occasions of instances when her professor would expect the class to have certain prerequisite knowledge that she did not have. In those instances, she reported that she would observe her classmates answering the professor’s questions, which caused her to question her own preparation and contributed to causing a decrease in her feeling of competence in mathematics.

Wanika also reported feeling unprepared for college and college-level mathematics. Speaking of under-preparation for college in general, Wanika stated:

I used to think [college] was going to be easy because teachers in high school would say, “yeah you’re going to have a good time because you’re one of the smartest students” and then I realized no I’m not, I’m an average student and college is harder than they make it seem in high school. You have to really try in college...In college they really challenge you...You have to stop being lazy, you have to actually use your mind and I wasn’t really prepared for that but I’m like let’s just do this, challenge accepted.

Specific to college mathematics, she said, “In reality high school didn’t really prepare me for math and it kind of threw me off. High school or elementary school didn’t really prepare me for math.” Although Wanika did not experience a decrease in her feeling of competence in mathematics—because she reported a low feeling of
competence in high school and continued to report a similarly low feeling of competence in college—her feeling of under-preparation caused her to continue to question whether she had the potential to succeed in college-level mathematics. The participants of this study were the top students in their high school, particularly in mathematics and science, so they likely did not anticipate that they would feel unprepared in college mathematics courses. This shift negatively impacted their mathematics identities when they moved from senior year of high school to freshman year of college.

**Factors Pertaining to the Mathematics Professor**

Factors pertaining to the mathematics professor include feeling encouraged to (or discouraged from) participating in class, perceiving that the professor is willing and available to help, and perceiving the professor to be of good (or bad) quality. All participants spoke of at least one of their mathematics professors as having an impact on their mathematics identities. Past studies have also highlighted the impact that professors have on students’ experience in college and college mathematics (Person, 2012; Powell & Berry, 2007; Tinto, 2007). In this study, there was variety in whether these factors contributed positively or negatively, depending on whether the participants perceived that they were having a positive or negative experience with their mathematics professor.

**Fostering Participation**

Several participants reported that their mathematics identities were impacted by whether or not they perceived that the professor fostered participation in class. Two of the participants (Isabella & Victor) reported a positive experience. Isabella
explained that her discrete mathematics professor not only encouraged, but required, participation. At first, required participation made her nervous but eventually it positively impacted her feeling of competence in mathematics. She explained:

The teacher would use index cards to randomly call on students: In my discrete class you had to talk, that was part of your grade. He has index cards and he has all of them looking down and he’ll pick one and read your name and you have to know what’s going on. If he called on you and you were not ready, he’d take points off. And I really like that. At the beginning, I was so nervous, I was the first one to be called on the first day of class. I was like oh no...but as time went by I really liked the class. I liked being called on because then I can show I was paying attention to whatever he’s doing in class, I know what I’m doing. And that helped me also with my homework because when you know that somebody is going to call on you, you want to try more.

Although Victor’s professor did not require participation, he believed that the professor was encouraging in inviting the students to participate and ask questions. This encouragement positively impacted his sense of belonging in mathematics. He shared, “I felt like I belonged. She encouraged [students to participate]. She wasn’t upset when you asked a question and she had to stop. She’d just stop right there if you had a question.” Timothy had almost the complete opposite experience in his college-level mathematics course. His sense of belonging was negatively impacted because he perceived that the professor did not foster participation and asking questions. He explained:

I hesitate to ask questions in class because the classes are so big that you feel like your questions are insignificant...If [the professor] has time to answer them, he’ll call on you but if not he’ll just say he doesn’t have time to answer questions.

The above participants reported that their mathematics identities were impacted either positively or negatively, depending on whether or not they perceived that the professor created a learning environment that fostered participation.
Willingness to Help

The mathematics identities of three participants (Hope, Isabella, & Victor) were positively supported when they perceived that their mathematics professor was willing and available to help them when needed. The following excerpts demonstrate the ways in which these participants reported that their mathematics professors were willing and available to help:

Hope: After each class, [my calculus] professor would have a little session if we had questions right after class we could just ask her...and she gets to know us. I feel like that’s what helped me and my friend.

Isabella: If you needed help [my discrete professor] would be there like come on, you can do this. I went to him for help, office hours and after class. In class we had a little session for our homework problems, if you didn’t get them he’d be like whoever has questions on the homework please let me know and I’ll do the problem on the board.

Victor: All of the professors knew my name so if I was struggling, they would email me and be like Victor you’re not doing something right and I’m worried you might fail. So we’d have a meeting one on one and they’d help me...[My math professor] really wanted everybody to pass so she’d come a whole three extra hours early for class and the whole class would be in the library and she’d be there three hours early just to help us...She took it on herself to do that.

These experiences positively impacted their sense of belonging (Hope & Victor) and their feeling of competence (Hope, Isabella, & Victor) in mathematics.

Quality

All seven participants reported that at least one of their college mathematics professors had an impact on their mathematics identities. They most often spoke of the impact in regard to whether they perceived their professor to be of good quality or of bad quality. The reader should note that quality has not been defined in this study; whether or not a participant perceived a professor to be of high quality was entirely
based on her own definition of *quality*. Perceived professor quality had a positive impact on the mathematics identities of a subset of the participants (Hope, Isabella, Timothy, Victor, & Wanika) and a negative impact on a different subset (Hope, Isabella, Naida, Ruckshana, Timothy, & Victor). Isabella provided an example of a professor that she perceived to be of good quality. She reported feeling that her discrete mathematics professor “really cared about the grade.” She credits him with encouraging her to persist with her mathematics-intensive major, even though she was having difficulties in the course:

> My discrete professor made me stay [in my major] because the way he was teaching stuff and the way he talked to us, I was like OK there are still professors who care about you. He was like I don’t want this class to be the reason you guys drop.

This encouragement positively impacted the desire to continue studying mathematics component of her identity. On the other hand, Victor provided an example of a mathematics professor who he perceived was of poor quality. He explained:

> [My developmental math professor] did a lot of talking. We came into class, he had the problems already there, on the desk we had to come in and grab it and sit down and then he’d go over the problems. He’d just write it on the thing. It wasn’t really hands on, he’d just write and we had to copy the answers down.

This teaching style negatively impacted Victor’s feeling of competence in mathematics. Isabella and Victor’s excerpts above serve as examples of how the participants reflected on the quality of their college mathematics professors. It should be noted that the participants were not specifically asked to reflect on the quality of their mathematics professors, yet all seven elected to comment on this.
Outside-of-Class Support Factors

All five participants who were involved in a college support program (Hope, Isabella, Naida, Ruckshana, & Victor) reported that they experienced outside-of-class support factors that positively impacted their mathematics identities. This finding is not unique, as extensive research exists supporting the effectiveness of such programs (e.g. Engle & Tinto, 2008; Engstrom & Tinto, 2010; Moreno et al., 1999; Morning, 2012; Tinto, 1987). The particular factors that reportedly benefitted the participants of this study included an increased likelihood of working collaboratively with peers, extra tutoring opportunities, and extra academic advising. The college support program was a state-funded program for low-income students that provided some financial aid, extra advising, extra tutoring, and a residential summer program during the summer between high school and college. During the residential summer program, members took introductory college courses. Members of the program who were placed into developmental-level courses often took these courses during the summer session so that they could begin in the fall with credit-bearing courses.

Although the college support members reported benefitting from an increased knowledge of campus resources, an increased sense of belonging in college, and access to advising, these benefits did not directly impact their mathematics identities. However, the push for collaborative learning and tutoring opportunities greatly benefitted the members over the non-members. The greatest apparent benefit of college support program membership was the encouragement of collaborative learning.
Benefit of Working with Others

The participants who were members of a college support program (Hope, Isabella, Naida, Ruckshana, & Victor) all reported that they worked with others in mathematics. Working with others included seeking tutoring and working collaboratively with peers. Ruckshana explained the importance of working with others, stating:

In order to understand something, you need someone to help you understand it. If I don’t understand something, I would go to someone who understands it and she would help you. It’s always good to have that support system, somebody who is knowledgeable of the subject and can help you through the problems so then you actually understand the problems...You need to go out and look for the help. If you don’t know something, don’t just sit there and pretend like the problem is going to go away because it’s not. You have to be the one to make that effort, go somewhere, ask for extra help. So for college level math, you have to do that too. You can’t just expect you’re going to know everything.

This was a major shift for Ruckshana, and many of the other participants, who stated that they did not work with their peers in mathematics in high school. For instance, Isabella explained that doing work in college mathematics “was completely different from high school. In high school I used to do my homework by myself. Now in college it’s like finding people who know how to do it.” I conjecture that membership in the college support program helped to encourage these participants to work with others in mathematics.

Benefit of Working Collaboratively

All five college support program members reported working collaboratively in mathematics (Hope, Isabella, Naida, Ruckshana, & Victor). Perhaps not coincidentally, the two non-members both reported that they did not work
collaboratively in mathematics (Timothy & Wanika). With one exception (Naida), the college support program members all explicitly mentioned that they collaborate with their college-support peers. Of course, co-occurrence does not necessarily mean causation, but the co-occurrence was so cut-and-dry that it could not be ignored. Nonetheless, whether or not the college support membership was the cause of the participants’ decision to work collaboratively, the benefit of collaboration was evident. This finding is reinforced by past literature highlighting the benefits of peer collaboration (Engstrom & Tinto, 2010; Powell & Berry, 2007; Tinto, 1987; Treisman, 1992; Walker, 2006). In this study, working collaboratively positively supported the sense of belonging in mathematics and belief in the ability to succeed in mathematics components of the participants’ identities.

The five participants who worked collaboratively in mathematics spoke about how collaboration helped them to understand the material in ways that they may not have if they had worked exclusively on their own. Hope explained, “I feel like [working with my peers] helped me more. Let’s say I have a question. I would ask them, they would explain it to me, and then I would understand it more. You hear it over and over and over again so that helped us.” Ruckshana not only found collaboration to be helpful, but actually essential. She stated:

Something that you definitely need [is a peer group] because if you don’t have that, there’s no way you can get through college on your own. You probably have to be a super genius to get through college on your own because you need your friends’ support or you need someone who is super smart in the class to help you understand the material... that’s something in college that you need, you need someone to count on, especially with your math and science classes, you can’t do it alone because you need that extra support. Some people are better at something than you are and you’re taking the same classes as they are so they’re gonna be the ones to help you with that. Networking. And I realize studying together with people helps a lot because when you talk
about the concepts and stuff like that, there’s so much teamwork in college, now that I’m talking about it, there’s so much teamwork in college.

Like Ruckshana and Isabella, Hope also stated that she did not work collaboratively in high school. She said that she did not work with other people because:

I’m not going to explain everything to other people. It was just like I was trying to do my work, with another person who doesn’t know how to do their work. So I first need to explain it to them and then do my work. It was too much so I would just do it by myself.

It was common for the participants to report that they did not work collaboratively in high school, but that they found collaboration to be essential in college.

The two non-members (Timothy & Wanika) both reported that they did not work collaboratively with their peers in college mathematics. When asked about working collaboratively, Timothy stated, “I don’t really talk to anyone in my actual classes...In the lecture everyone just sits there quietly, you don’t really interact with your classmates.” Wanika had a similar response, stating, “I don’t think there were study groups. Everybody seemed like they don’t know each other. Get in, get out...Basically it was like bye, everybody goes back to the dorms.” It should be noted that Ruckshana attends the same school as Timothy and Wanika, and took some of the same courses, yet she participated in study groups in every single one of her mathematics and science courses.

**Benefit of Receiving Tutoring**

A similar trend was seen in tutoring; with one exception (Naida), all of the college support program participants reported that they received tutoring in mathematics. Although Naida did not attend mathematics tutoring, she did receive tutoring for her writing class, demonstrating that she was aware of and open to
tutoring options. The two non-members reported that they did not receive tutoring. Tutoring positively supported the participants’ belief in the ability to succeed in mathematics. Researchers have recommended that college students take advantage of tutoring opportunities (David, 2010; Engle & Tinto, 2008). Hope stated that she attended tutoring because “Tutors are a big source of information and help. Since they already took the class and probably with the same professors, they would know and help me with what things to study.” The participants often credited the college support program with referring them to tutoring services. In fact, several participants revealed that if campus-wide tutoring was unavailable for a particular class, the college support program would provide tutors (Hope, Isabella, & Victor). For Hope and Isabella’s college support program, tutoring was required. Victor’s program required study hours in the library and would provide tutors upon request.

On the contrary, the two participants who were not members of a college support program (Timothy & Wanika) both reported that they did not attend tutoring. Interestingly, they both stated that they should have gone to tutoring but did not and both of these participants failed precalculus. Timothy and Wanika both expressed confusion in how to receive tutoring services:

Timothy: They’ll tell you about the tutoring during the class or maybe you meet with one of the deans and they tell you there’s tutoring available and where to go...I’m pretty sure they have them for all of your difficult classes. They probably have them for math. I didn’t go but I should have...[My school] provides it for free. You would have to look for it online. I think that’s one of the things that makes people not go. They don’t provide you with the exact times, you have to find that out by yourself.

Wanika: There are tutoring sessions but you have to find them yourself...If you need extra help, they’ll tell you the places but you have to go to them yourself. I see posters but I don’t know where they are or I don’t feel like going...I should have, but I didn’t and I regret
that. I should have gone and gotten help when I needed it and not waited too long to get it...They have math tutors, but I don’t know where. They have posters all around but they don’t tell you where. I don’t know if it’s paid or you have to pay for it, they don’t give you too much information, they just tell you go to this.

Recall, again, that Ruckshana attended the same school as Timothy and Wanika and yet did not have difficulty seeking tutoring. This unique situation provides further support to my conjecture that college support program participation encouraged students to work with others in mathematics.

Factors Outside of the College

Lastly, the participants reported one factor outside of college that impacted their mathematics identities: family involvement. Contrary to the stereotype that parents of underrepresented students are uninvolved in their children’s education (e.g. Baker & Stevenson, 1986; Lareau, 1989; Muller & Kerbow, 1993; Sampson & Raudenbush, 1999), five of the seven participants of this study (Isabella, Ruckshana, Timothy, Victor, & Wanika) cited family involvement as a factor that contributed to their mathematics identity. For four of these participants (Isabella, Ruckshana, Timothy, & Victor), this family involvement was supportive but for one (Wanika) it was discouraging. The remaining two participants (Hope & Naida) did not speak of their families as being involved in their education, and both believed that their family did not understand what college entailed.

Supportive Family Involvement

Supportive family involvement came in the form of encouraging advice (Ruckshana & Timothy), support from relatives who had experienced college (Isabella & Ruckshana), and extrinsic rewards (Victor). This support may not have helped
students directly in their mathematics courses, but it helped encourage them to succeed in college, in general. When asked what has supported him in his pursuit of a career as a veterinarian, Timothy explained:

   Whenever I have any doubts about what I want to do, I just talk to my family about it and they say it’s hard at the beginning and it’s tough but you just have to stick with it because eventually you’re going to get to that point when you look back and you just had to do all that work to get where you want to be. You can’t avoid it, everything you do takes hard work so if you just ride it out, everything will work out in the end.

Ruckshana agreed that her family’s advice is a source of support, stating:

   It’s nice to have that family support. If I need any help with something, I’m going to go to them and ask them am I making the right decision in what I’m doing with my college career. They’ll be the ones to tell me.

Even more concrete than encouraging advice, Isabella and Ruckshana felt supported by their families because they had older relatives who had experienced college. Isabella’s sister was a year older and was a biology/premedical major at the same college. Isabella would go to her sister for guidance and for help in classes that she had already taken. Ruckshana had several older cousins who had attended college and majored in mathematics-intensive fields. They offered her advice in what majors to declare and what internships to pursue. One last participant, Victor, indicated that family support was a factor that encouraged him. His mom was a source of motivation to succeed in college mathematics because he did not want to disappoint her and fail. She offered an extra source of encouragement by offering Victor money in return for making the Dean’s List. These participants provide evidence against the stereotype that families of underrepresented students are uninvolved in their education.
Discouraging Family Involvement

For one participant, Wanika, family involvement was actually discouraging. Phelan, Yu, and Davidson (1994), in their study of urban students’ school experience, found that “the most frequently cited family stress by students in this study (78%) is that their parents pressure them to do well in school” (p. 431). This finding is aligned with the experience of Wanika, who reported that her mother was very involved in her first year of college. Unfortunately, her mother’s involvement was discouraging for Wanika and was a pivotal factor contributing to her decision to switch college majors. Her mom’s involvement made Wanika doubt her feeling of competence in mathematics—“my mom’s like you know you’re not good at math, she always constantly reminds me I’m not good at math,” her career plans—“my mom’s like you know there’s other things you can do [besides working with animals], you can make more money...my mom was like you know you’re not really good at math, maybe you should do something else,” and her confidence in mathematics classes:

No offense to my mom, but she’s not really encouraging so I tend not to tell her when I need help or when I’m failing in a math class because she’s not encouraging...I get really nervous during math tests because I know if I don’t pass this then [my mom is] going to yell at me and then I won't be able to do what I want to do and graduate on time...If I don’t [get help] I’m gonna fail and then my mom is going to yell at me that I need to spend more money in college.

Wanika was so influenced by her mom’s involvement in her education that she mentioned it during all three interviews. Her case can serve as an example of discouraging family involvement.

Uninvolved Families

Hope and Naida were the only two participants who did not speak of their families as being involved in their college education. Interestingly, both participants
felt that their families did not understand what they were going through in college. This finding was echoed in past studies (Thayer, 2000; Tinto, 1987). Naida attributed her family’s lack of involvement to her culture, explaining her belief that Hispanic families could be categorized as one extreme or another. She stated, “you either achieve or just fail…it’s either good or it’s bad, there’s nothing in between.” She explained how this dichotomy manifested in her own family by stating:

when you’re Hispanic, you either have parents who want you to do good or you have parents who don’t care about it. And I have parents that really don’t care…my mom, she never understood, and I was trying to make her understand, but that just made me want to [stay in school] more.

Hope also described experiencing a lack of family involvement in her education. She felt that her family did not understand the workload that was involved in being a college student. She explained:

Let’s say I would be doing homework and all day every day I would be in the library, just studying over stuff and my parents or my sister will text me asking what I’m doing, have I been eating right, have I been sleeping and I’m like no I can’t eat I can’t sleep I can’t do anything, I’m just doing homework and they’re worried. And sometimes when I have to come back home I’m like OK I can’t come back for a month or after this date and I’m like I can’t talk to you or come back home until after this date and they’re like you haven’t been here in a month what are you doing and I’m like I can’t I’m doing homework all the time and studying and they don’t understand it.

This family situation was particularly concerning for Hope because she was registered for a summer course at her local community college and would be living at home while taking the course. She explained her concern stating, “I don’t know how I’m going to do it because I’m living at home and [my family is] like let’s go out, let’s go to the beach, I don’t know how I’m going to do it.” Although Hope and Naida are both first-generation-college students, which may help to explain the lack of family
involvement, other first-generation participants (Isabella, Ruckshana, & Victor) stated that their families were involved during their first year of college.

**Impact of the Underrepresented Status of the Participants**

The participants were asked to reflect on different aspects of their underrepresentation in mathematics (low-income, first-generation-college, race/ethnicity, gender if applicable, and non-English first language if applicable) and whether this underrepresentation had an impact on their experience in college mathematics. More than any other qualifier for underrepresentation, the participants reported that attending school in a low-income district negatively impacted their mathematics identities. On the contrary, underrepresentation by race/ethnicity, gender, and non-English-first language had little reported impact on their mathematics identities. Being first-generation-college only impacted three participants, but it was substantial for the college experience of these three.

**Underrepresentation by Income**

With the exception of one participant (Victor), all of the low-income participants reported that attending school in a low-income district negatively impacted them in college mathematics. It impacted their feeling of competence in mathematics and their belief in their ability to succeed in college mathematics. Hope and Isabella both felt disadvantaged because they believed that their low-income school district offered fewer mathematics courses than the districts of their peers. Isabella explained that she felt behind her peers in discrete mathematics for this reason, as she had taken fewer college-level mathematics courses than they had:

I was one of the few students in Discrete taking Calc A. Everyone else in my class was taking Calc B. Now seeing that they know more than
me it’s like oh my God, now I have to force myself to get to their level which has been kind of hard. They don’t offer as many classes [at my high school] so my classmates are one step above me and I have to force myself to learn more.

A look into the course offerings in the participants’ high school district revealed that this is in fact the case; at the time of data collection, their school district stopped offering algebra in middle school. All students in the district would begin high school with algebra 1. Counting forward on a traditional mathematics sequence to senior year, very few students in the participants’ district would have the opportunity to take calculus in high school. Isabella was one such student; once enrolled in college-level mathematics courses, she noted that she was behind her peers in her high school course completion.

Wanika also felt disadvantaged in mathematics because of her education in a low-income school district. She stated:

Not many people [from my city] go to college and you can just tell and they’re kind of proud of that. But I’m like no I want to rise above my means, I want to prove to everybody that I’m not just some ghetto person from the streets, I have a college education and I want to go places. I don’t want to just stay here on welfare, I want to be more than that...But my math came from [my city’s education system] and it’s not that great. They don’t really show you how to do math.

Wanika’s belief that she did not receive an adequate mathematics education in high school (actually, in K-12) was consistent in both studies. She often spoke of being passed along from one level of mathematics to the next without ever demonstrating mastery of the material. She perceived that she was given passing grades in mathematics for having good attendance, being attentive, being polite, and appearing studious, but not for truly showing understanding of the material. Wanika felt that she was paying for her lack of mastery of the material in college; she had already failed precalculus (a mathematics requirement of her animal science major) twice. A follow-
up conversation after the conclusion of this study revealed that she had failed a third time. Even after switching from a mathematics-intensive major (biology) to a non-intensive one (animal science), Wanika continued to question whether her education had adequately prepared her to pass college-level mathematics courses.

The following lengthy but illustrative excerpt from Ruckshana captures the experience of an underrepresented student comparing her preparation from a low-income school district to the preparation of her peers. She stated:

Coming from a low-income city, there are people I met who came from these big time cities with schools facilitated with better education or with harder work in their classes, but in high school you go to public school and there’s students who don’t even care about their classes. They just want to cut classes and do drugs and do who knows what they want to do. I remember in high school I realized people would say high school was such a joke. It’s nothing compared to what college was like. The stuff can’t even touch the amount of effort we have to put into college. In high school we didn’t have to put in that much effort. We come home do no homework, the next day before the class we do the homework and have some way to just get by and still get an A. Or cut class but the teacher is still nice enough to give you a B. I was aware that our school was not a hard school to get the good grade in the class...I knew we weren’t doing as much as we could be doing. I knew they weren’t doing much for us, even more when I went to college. Learning the actual material in college, I had to do myself on my own. I was teaching myself in college but you don’t learn that in high school. That’s why we say that high school is a joke. Because it’s like alright I’m jumping into this big college and it’s just hard classes and it’s going to hit you hard once you get to college. Joke of the year, high school. [My other high school friends] were saying how it’s so hard they have to put so much work and time and effort in precalc in college. They also said the same thing, how it’s so hard. We always talk about how there’s a big jump. Even my [older] cousins told me that the transition from high school to college is what really hits freshmen hard. Because they don’t expect it and they don’t really know how to study yet because they haven’t explored studying methods in high school. And that’s what happened to me. You actually learn in college. High school you just get by and you’re good
to go. But college you definitely learn. Coming from a low-income environment, you can see the difference.

The participants of this study were among the top-performing students in their high schools, particularly in mathematics and science. Until arriving in college, they likely did not have an opportunity to compare their education to the education of students in more-affluent districts. Thus, it is not surprising that coming from a low-income school district had such a large negative impact on the participants’ mathematics identities immediately following completion of their first year of college.

Underrepresentation by being First-Generation-College

Only three of the five first-generation-college participants (Hope, Naida, & Victor) reported that being first-generation impacted their college experience, but it had a substantial impact for these three. It should be noted that being first-generation-college did not directly impact the mathematics identities of these participants, but it impacted their experience in college, generally. For Naida and Victor, being first-generation had a simultaneous negative and positive impact on their college experience. It was negative in that they reported feeling an ever-present pressure to complete their degree, which was overwhelming at times. In the same vein, being first-generation at times had a positive impact because they reported that it was a source of motivation. The following excerpts illustrate this dichotomy:

Naida: I’m the first one, you have to do it, you have to pave the way for everyone else that’s going to be behind you. So it’s a lot of pressure. It’s like oh Naida you’re the first one to go to college, we’re so proud of you, and you try to live up to that, you try to make the people you love happy. So it’s a lot of pressure and I feel like when you go to college there’s so few of us [who are first-generation]. I know people that both of their parents have masters or doctorate degrees and my father made it to the third grade or something like that. You know, it’s hard, there’s so many people that come from privilege and they
complain so much and you’re like I’ve never had that, you can’t complain. So it’s hard to deal with seeing other people have it or have those opportunities that you want, or see other people not have to try as hard as you. I think that’s the hardest part. It’s like I’m the same as you, we’re just human, we want the same things, we just grew up differently. So that’s hard, I think the unfairness that you see. At the same time, it’s an advantage because I think it pushes you because you feel like some people believe that you can’t make it so I think that pushes you to prove them wrong in a sense.

Victor: It’s a lot of pressure, but it’s the good pressure. You’re happy that you’re the first one in your family to go to college but you don’t want to disappoint your parents. I don’t want to disappoint my mom and come here and just play around and fail. I made her happy by coming here but I’d disappoint her by not sticking to it, not finishing it. So it’s very impactful. It’s bittersweet. You’re happy to be here but you gotta work hard. It’s bittersweet like I said. I’m happy to be here but the other side is you gotta put your priorities together and know what you’re really here for.

For Hope, being first-generation impacted her school experience because she perceived that her family did not understand the workload involved in being a college student. She lamented, “they just don’t understand how the workload works.” Although the first-generation status of these participants did not directly impact their mathematics identities, it had a great impact on their college experience generally.

Underrepresentation by Race/Ethnicity, Gender, and Non-English First Language

With the exception of one participant (Wanika), being underrepresented by race/ethnicity, gender, and non-English-first-language had no reported impact on mathematics identity. Appendix C provides institutional demographic data (gender and race/ethnicity) for the colleges attended by the participants. The participants who were underrepresented in these ways sometimes noted stereotypes or indicated awareness of being a minority in mathematics, but they did not report that it impacted
their mathematics identities. For instance, regarding being female in mathematics classes, Naida stated:

I never know how to answer these questions because I don’t think I’ve ever really experienced that, just because I’m female. I just see everyone as a human, we’re all the same. I see not as many females going to math classes, I see that, but I don’t really notice it.

In a similar instance, Isabella discussed being Hispanic in mathematics classes, stating:

At the school that I go to, there’s not a lot of Spanish people there. I think I’m one of the few who major in math...So it looks like not a lot of Spanish people like to major in the math field...I don’t think it’s had an impact, just something I made note of.

The above statements are representative of the entire sample (Wanika being the exception), with the participants being aware of their underrepresentation but not believing that it had an impact on their own identity in mathematics.

**An Exception**

Wanika was the exception to this theme. Her identification as African American had a strong impact on her mathematics identity. She explained:

When I do look around, there’s not many black people in my class so I feel kind of out of place, but I try to look past my skin color because nobody is even noticing that. It just seems kind of weird that there aren’t any African Americans in the math classes or the science classes and I think we’re sparse in that area because I think we just don’t click in this area sometimes. And it’s kind of sad, because I don’t feel comfortable a little bit sometimes, because I feel out of place in some classes, looking around, and I’m like there’s not any people of my color here...and I felt kind of out of place like I had to prove myself like I’m just as good as you guys are. My high school was pretty much black and it was like I feel comfortable here...but then you go to college and it’s a whole different ball park and I’m like I’m not really ready for this.
At the completion of her first year of college, Wanika was struggling with many aspects of her mathematics identity. Her racial identification, in particular, had a reported negative impact on her sense of belonging in mathematics and her feeling of competence in mathematics.

**Summary**

The participants of this study indicated several factors which contributed, both positively and negatively, to their mathematics identities. Some of these factors stemmed from a comparison of their experiences in high school mathematics to their experiences in college mathematics. These included differences in study skills, a lack of experience with graphing calculators, and feeling unprepared for college-level mathematics. Within the mathematics classroom, the participants reported that their professors had an impact on their mathematics identities through fostering participation, showing a willingness and availability to help, and being perceived as high quality.

Outside of the classroom, a subset of the participants appeared to experience several benefits from participating in a college support program. Although there were many reported benefits to participating in such a program, two benefits specifically supported the participants in mathematics: encouragement to work collaboratively and extra tutoring opportunities. One other factor outside of the mathematics classroom impacted the participants’ college experience and this was the reported family involvement in their education. Family involvement had both negative and positive influences on the participants’ college experiences. These contributing factors inspire a discussion on how stakeholders at various levels (high school, postsecondary, and policy) can work to improve the retention of underrepresented
students in mathematics-intensive postsecondary degrees. These ideas will be elaborated upon in the following chapter.
Chapter 6
DISCUSSION

This exploratory study sought to uncover factors that were experienced by underrepresented students that contributed to their mathematics identities during their first year of college, according to the students themselves. The seven underrepresented college freshmen who participated in this study represent an important group to investigate for several reasons. For one, being that they are low-income and/or first-generation-college students dictates that they will likely face a unique set of challenges in their transition to college-level mathematics. Engle and Tinto (2008), in their report on the college experience of these particular groups of students, found that “the combined impact of being both low-income and first-generation puts these students at risk of failure in postsecondary education” (p. 1). Thayer (2000) explained that “because students from first generation and low income backgrounds are among the least likely to be retained through degree completion, institutional retention efforts must take the needs of such students into account if more equitable educational attainment rates are desired” (p. 1).

Secondly, these particular students are an important group to study because they had all developed aspects of positive mathematics identities by their senior year of high school, as indicated by the findings from my prior study (Marzocchi, 2013). Each of the seven participants expressed an aspect of positive mathematics identity through their decision to continue studying mathematics (through a desire to pursue a mathematics-intensive college major and a mathematics-intensive career). Powell and
Berry (2007), whose research program involves an investigation of successful underrepresented students, believe that it is important to focus on underrepresented students who have had positive mathematics experiences. They noted that “it is critical to examine perceptions and experiences of students who are accomplished” so that more underrepresented students will be similarly positioned to succeed (p. 169).

For the participants of this study, one could say that the recruitment aspect of the problem has been satisfied—as indicated by the participants’ desire to pursue mathematics-intensive degrees in college—and this study helps to move forward with an examination of their retention. Engle and Tinto (2008) indicated that:

> it is no longer enough to be concerned only about whether low-income and first-generation students to go college. We also must be concerned about where and how they go to college – and the experiences they have once enrolled – to ensure that this population can stay there through the completion of a degree. (p. 5, emphasis in original)

Additionally, being that the participants of this study represent a cohort of mathematically-inclined underrepresented students, if they were struggling, it is likely that others are struggling.

> It is beneficial for institutions to gain knowledge on the college experience of underrepresented students. The exploratory nature of this study allowed for the investigation of the college experience from the perspectives of underrepresented students themselves. Thayer (2000) explained, “strategies that work for first generation and low income students are likely to be successful for the general student population, as well” (p. 1). This explanation could account for why some of the factors revealed in this study (the benefit of collaboration in mathematics, for instance) are not unique to the population of underrepresented students but would likely benefit the general college student population. Thayer (2000) goes on to explain that, by
contrast, “strategies that are designed for general campus populations without taking into account the special circumstances and characteristics of first generation and low income students will not often be successful for the latter” (p. 1). Although it is possible that some of the results of this study may also be applicable to non-underrepresented students, this possibility is a benefit, not a detriment.

Lastly, a major contribution of this work is that it investigated students’ identity changes by applying the same model of mathematics identity (see Figure 1) at two distinct time points: one before experiencing the transition (end of senior year of high school) and one after experiencing a transition (after completing the first year of college). Only one other study in the reviewed literature (Nasir, 2002) investigated identity change. Nasir (2002) reported on how students’ identities changed as they became better at games, namely dominoes and basketball. Unlike Nasir’s (2002) study, this study investigated identity change before and after students experienced a major transition—the transition from high school to college mathematics. By applying the same model of mathematics identity (see Figure 1)—which was validated through the exploratory methods of this study—at each time point, I was able to make claims about how the participants’ identities changed over time and was able to uncover factors that contributed to those changes. This method appears to be unique to this study and other researchers are encouraged to apply this model similarly.

**Divergence between the Literature and the Findings of this Study**

Many of the results of this study aligned with findings from prior literature. This alignment was discussed throughout the Results chapters and will be discussed throughout this Discussion chapter. However, there were several ways in which the findings of this study did not converge with the literature. This divergence included
findings in the literature that were not present in my data and findings in my data that were not present in the literature.

**Factors Missing from the Literature**

This exploratory study uncovered factors unique to this study which the participants reported as contributing to their mathematics identities. Specifically, the factors that fall under the “high school to college comparison factors” category were unique to this study. I conjecture that the discovery of unique factors could be attributed to the rare investigation of identity *change* that was employed in this study. By allowing the participants to reflect on their college mathematics identities in comparison to prior results on their high school mathematics identities, factors emerged that compared high school to college. Although past research has reported on the under preparation of underrepresented students for college (Engstrom & Tinto, 2010; Moore et al., 2010; Nasir, 2002; National Center for Education Statistics, 2005; Thayer, 2000; Tinto, 2007; Tinto, 1987; Treisman, 1992; Tyson et al., 2007; Walsh, 2010), much of this work has been quantitative in nature and only investigates preparation at one time point. In this study, the participants themselves reported on how their high school experience in mathematics impacted their mathematics identities in college.

In particular, two of the factors were unique to this study: inadequate study skills and lack of graphing calculator experience. Many prior studies discussed the ill-preparedness of underrepresented students for college and college mathematics (Engstrom & Tinto, 2010; Moore et al., 2010; Nasir, 2002; National Center for Education Statistics, 2005; Thayer, 2000; Tinto, 2007; Tinto, 1987; Treisman, 1992; Tyson et al., 2007; Walsh, 2010), but none explicitly discussed study skills. The lack of discussion of
study skills was surprising because all five of the participants of this study who discussed that their feeling of competence in mathematics decreased during their first year of college also discussed that their study skills were inadequate. However, as mentioned above, this absence from the literature could be attributed to the unique investigation of identity change in this study; when asked to reflect on results from a study of the participants in high school, they were given the opportunity to compare the study skills that were required in each setting. The results for this study highlighted a link between inadequate study skills and decreased competence in mathematics and, hence, this is an area deserving of further exploration.

The literature reviewed for this study also did not discuss a lack of preparation for using mathematical technology (such as graphing calculators) as having an impact on underrepresented students’ success in college mathematics. Again, this absence could be attributed to the unique investigation of identity change in this study. When prompted to compare their high school mathematics experience to their college experience, the participants may have been more likely to note the difference in their graphing calculator usage in each setting. Although only three participants in this study discussed struggling with the graphing calculator, this struggle had a substantial impact for those three; they each reported that their grades in their mathematics courses suffered as a result. From the results, it appeared that graphing calculator fluency was assumed by mathematics professors to be a prerequisite skill. The participants of this study, and likely many other students from low-income school districts, did not have the opportunity to build this fluency. Their ability to succeed in college-level mathematics was negatively impacted, making calculator fluency another important area to explore.
Factors Missing from the Findings in this Study

Several factors that were discussed in the reviewed literature did not reveal themselves in the data of this study. For one, past research (e.g., National Center for Education Statistics, 2005) has indicated that underrepresented students are less-likely than their non-underrepresented peers to select mathematics-intensive majors. Given the small number of participants in this study, it is not fruitful to make claims about the rate at which the participants selected mathematics-intensive majors. However, there is promise in knowing that, despite being members of underrepresented population groups, all of the participants of this study had the intention of pursuing mathematics-intensive majors. Of course, it should be noted that these participants were the same students who chose to enroll in a math/science outreach program in high school, indicating that they are likely more mathematically-inclined than a general population of underrepresented students. That being said, the participants of this study serve to provide insight into the experiences of underrepresented students who, against the odds, had the intention of pursuing mathematics-intensive degrees.

Another finding from the literature (e.g., Person, 2012) that did not manifest in this study was the impact of race/ethnicity on participants’ mathematics identities. Person (2012), who studied the retention of underrepresented college students, found that when racial minority college students attended predominantly-White colleges (which was the case for all of the participants of this study), their race/ethnicity had a large impact on them in their college mathematics courses, particularly impacting their sense of belonging. Recall that Wanika reported that her identity as African American led her to question her own sense of belonging and feeling of competence in mathematics. However, the remaining six participants reported that their mathematics identities were not impacted by their racial identity.
Lastly, past literature indicated that financial difficulties were a source of struggle for low-income college students (Appleby & Cox, 2002; Engle & Tinto, 2008; Thayer, 2000). The participants of this study did not discuss personal finance as being a source of difficulty. Recall that they cited disadvantages stemming from attending high school in a low-income district (fewer mathematics course offerings in high school, for instance) but they did not discuss any personal financial difficulties. That the participants did not discuss personal financial difficulty is surprising considering all but one participant (Timothy) are classified as low-income. However, all but one (Wanika) of the low-income participants were members of a college support program that provided some financial assistance, which could account for the absence of this factor in the findings of this study.

WHY are Underrepresented Students Completing Mathematics-Intensive Degrees at a Lower Rate?

Existing quantitative findings have told us that students from the population groups of the participants of this study are completing proportionally fewer mathematics-intensive bachelor’s degrees than their non-underrepresented peers (e.g. Engle and Tinto, 2008). This exploratory study extended that finding by providing us insight into why there is inequity in degree completion, from the perspectives of an exemplary group of mathematically-inclined underrepresented students. The results of this study also allow us to discuss how to address this issue while taking into account the particular needs of the students themselves. By applying the methods of this study that uniquely investigated changes to the identities of the participants, two cases of participants were uncovered: those who switched off of a mathematics-intensive degree path and those who persisted on this path.
A Look at the Participants Who Switched off of a Mathematics-Intensive Path

The three participants who switched off of a mathematics-intensive degree path (Naida, Victor, & Wanika) reported negative mathematics identities in all three facets of their identities at the conclusion of their first year of college: Who am I?, Who do I want to be? and Who can I be?. Arriving at college and seeing themselves in comparison to their better-prepared peers in mathematics led them to question who they thought they were. In turn, beginning to question their own selves in mathematics led them to question who they believed they could be.

For these participants, the Who can I be? question of mathematics identity was impacted negatively as the participants questioned whether they could succeed in college-level mathematics. In Naida’s case, a change in who she believed she could be also caused her to change who she wanted to be. Naida reported no hesitation in switching her college major from business to law, as she found a new passion for law and stated that she was certain she did not want to take any more college-level mathematics courses. Naida reported being secure in her decision. Unfortunately, this was not the case for Victor and Wanika. Their uncertainty with the Who can I be? question of mathematics identity is what drove them to change their major but it did not change who they ultimately wanted to be. Victor reported that he still wanted to be an accountant but that he was likely not going to pursue that career because he doubted his ability to succeed in college-level mathematics. Similarly, Wanika reported that she still wanted to be a veterinarian but she gave up that goal when she was forced to confront the Who can I be? question of her mathematics identity. For these three participants, the root of their decision to switch majors was in their low feeling of competence in college mathematics, and their subsequent questioning of who they believed they could be.
A Look at the Participants Who Persisted

At the time of data collection, four of the participants were persisting on a mathematics-intensive degree path (Hope, Isabella, Ruckshana, & Timothy). Isabella, Ruckshana, and Timothy all experienced a decrease in their feeling of competence in mathematics, yet persisted on mathematics-intensive paths nonetheless. Although Timothy’s feeling of competence and sense of belonging had decreased, thereby leading him to question the Who am I? question of mathematics identity, he persisted as a biology major with the intention of becoming a veterinarian. He persisted because the Who do I want to be? question of his mathematics identity was a driving force in his college decision making. His passion for working with animals left him wanting to pursue nothing other than veterinary school. In fact, during his freshman year of college Timothy had already begun researching graduate veterinary programs. Isabella had a similar drive towards her future career goal. She, too, experienced a decrease in her feeling of competence in mathematics but, despite this, continued to view mathematics as a subject that is enjoyable and useful. For this reason, Isabella’s view of the Who am I? question of mathematics identity did not show significant change between high school and college. Like Timothy, Isabella strongly valued the Who do I want to be? question of her mathematics identity. She intended to become a high school mathematics teacher and could not envision herself doing anything else. Ruckshana, too, experienced a decrease in her feeling of competence in mathematics and thus experienced a change in the Who am I? question of her mathematics identity. However, Ruckshana took her decreased feeling of competence as an opportunity to rethink and improve her study skills in mathematics. In doing so, her Who can I be? question of mathematics identity was supported and she continued to want to be a biomedical engineer and reported that she believed that she could achieve this career
goal. Isabella, Ruckshana, and Timothy are similar in that they all experienced a decrease in their feeling of competence in mathematics, yet they persisted on their mathematics-intensive career paths nonetheless.

Hope was the only participant to report experiencing a high feeling of competence in college mathematics. Of all the participants, her mathematics identity was classified as being the most positive in high school and this continued into college. She had always seen herself, and continued to see herself, as someone who belongs in the mathematics community, someone who can succeed in future mathematics endeavors, and someone who is interested in pursuing mathematics. At the time of data collection, she was continuing on the path to a biology degree without hesitation. This is not to say that her college experience was without struggle—for instance, she unexpectedly failed precalculus—but her strong, positive mathematics identity supported her on her path to degree completion.

**HOW Can the Retention Problem be Addressed?**

College-level mathematics courses played a major role in the pathway to mathematics-intensive degrees for the participants of this study. The recruitment and retention of underrepresented students in postsecondary mathematics is a national concern and a shared problem of us all, whether mathematicians or mathematics educators, and whether high school level of college level (or elementary level, societal level, etc.) and the existing inequities in mathematics education must be addressed. Further, the economic well-being of our country is depending on efforts to address this issue of recruitment and retention (Curtin & Cahalan, 2004; Engle & Tinto, 2008; Gandara & Bial, 2001; Laguardia, 1998). This section will discuss efforts that can be made at the high school level, college level, and policy level.
High School-Level Implications

All of the participants of this study reported feeling that they were underprepared for college-level mathematics. For five participants (Isabella, Naida, Ruckshana, Timothy, & Victor), this feeling of under-preparation contributed to a negative shift in their feeling of competence in mathematics. Past studies have found that underrepresented students are disproportionately underprepared for college or for college-level mathematics (Engstrom & Tinto, 2010; Moore et al., 2010; Nasir, 2002; National Center for Education Statistics, 2005; Thayer, 2000; Tinto, 2007; Tinto, 1987; Treisman, 1992; Tyson et al., 2007; Walsh, 2010). The participants of this study often spoke of their high school mathematics courses as being easy compared to their college mathematics courses. One way to address this issue is to increase the rigor of high school mathematics courses and provide students with the skills that they need to succeed in rigorous courses. High schools may hesitate to make their mathematics courses more challenging for fear that students will become overwhelmed and disengage with the subject. In reality, findings from my prior study (Marzocchi, 2013) indicated that the participants were more likely to disengage with the courses that they perceived to be too easy (recall Naida sleeping in her high school precalculus course because she was so ahead of her peers, for instance), and not the ones that they perceived as difficult. Berry et al., (2011) saw similar results in their study of mathematically-successful Black boys. They stated, “mathematics should not be simplified or dumbed-down but rather teachers should hold high expectations for their students to solve challenging and complex mathematics problems” (p. 20). Perceiving a mathematics course as challenging positively supported participants’ mathematics identities.
College-Level Implications

The colleges of the participants of this study offered several mechanisms of support to their students. Some of these supports included tutoring opportunities, academic advising, and college support programs. However, not all of the participants were aware of how to access these opportunities (namely Timothy and Wanika). It is important for colleges to provide support to students in need and to make students aware of this support (Engstrom & Tinto, 2010; Tinto, 1987). Students who are in need of the support should be encouraged to attend by faculty and advisors. Tinto (1987) argued, “students accepted for admission should be given a reasonable opportunity to complete their program of study” (p. 138). If a student is admitted, it should be because the college believes that she has a fair chance of receiving a degree. If she struggles on the path to her degree, support opportunities should be available.

Engstrom and Tinto (2010) indicate that this is not always the case:

Access without support is not opportunity. That institutions do not intentionally exclude students from college does not mean that they are including them as fully valued members of the institution and providing them with the support that enables them to translate access into success. (p. 50)

Too many low-income students...enter college academically under-prepared, and too few find the support they need to succeed in college. As a result, their rates of completing four-year degrees continue to lag behind those of more-affluent students. (p. 47)

Fortunately, a lack of support opportunities did not appear to be an issue for the schools of the participants of this study. The participants reported that there were several support mechanisms in place; other colleges should follow suit.

One mechanism of support at the college level was the offering of college support programs. The five participants who were members of a college support program (Hope, Isabella, Naida, Ruckshana, & Victor) reported many benefits of
membership. These benefits included an increased knowledge of general resources in college, a reported feeling of a sense of belonging in college, access to an advisor with the ability to give more one-on-one attention, an increased knowledge of tutoring opportunities, and an increased likelihood of working collaboratively with peers. Past research has also found benefits of college support programs (Engstrom & Tinto, 2010; Moreno et al., 1999; Thayer, 2000, Tinto, 1987). Although these support programs are beneficial, they cannot be the only solution as they can be costly and they only benefit the small number of students enrolled in the program.

The participants also cited several factors pertaining to their mathematics professors as having an impact on their mathematics identity. These included fostering a learning environment where participation was encouraged, perceiving that the professor was willing and available to help when needed, and perceiving the professor to be of good quality. Past research supports the claim that professors play a role in the retention of students in college (Person, 2012; Powell & Berry, 2007; Tinto, 2007). Professors should be made aware of and held accountable for their actions which impact the retention of underrepresented students.

Related to the role of the professor, professors should be made aware that students are not necessarily arriving to their classes with graphing calculator fluency. The literature reviewed for this study did not discuss a lack of graphing calculator fluency as an issue for underrepresented students in college-level mathematics, but it was a substantial issue for a subset of the participants in this study. Each of the participants of this study reported having contact with graphing calculators fewer than twenty times in their entire high school career. One way that college professors can improve the graphing calculator fluency of their students is by borrowing a technique
known as pair programming from the field of computer science (Shah et al., 2013). Using the pair programming model, two students would share one calculator, with one student serving as the driver (actually pushing the buttons) and the other serving as the navigator (verbally giving instructions). Mathematics professors could assign a less-experienced student with an advanced student and have the advanced student start as the navigator. Every few minutes, the calculator is passed and the roles are switched.

Cooperative Efforts

The findings of this study revealed that there was an apparent gap between the high school expectations and the college expectations in mathematics for these participants. This gap in expectations points to a need for increased communication between high school teachers and college professors. The two parties must work together so that college-entering students are leaving high school with a reasonable chance of success in college-level mathematics. Addressing this gap may involve adjusting the expectations on both ends.

High school teachers and college professors would also benefit from professional development on collaborative learning in mathematics. They should learn how to improve collaboration both inside and outside of the mathematics classroom. Five participants of this study reported benefitting from collaboration in mathematics (Hope, Isabella, Naida, Ruckshana, & Victor). Past literature has also pointed to the benefits of collaboration (Engstrom & Tinto, 2010; Tinto, 2000; Tinto, 1987; Treisman, 1992; Walker, 2006). Similar to the participants of this study, the students in Engstrom and Tinto’s (2010) study reported that “collaboration helped them to feel less alone, more confident in their ability to succeed in college, and more supported in their studies” (p. 48). By encouraging collaboration at the high school
level, students may be more likely to seek collaborative opportunities when they arrive in their college-level mathematics courses. At the college level, professors should recognize the many benefits of collaboration and encourage their students to form study groups.

Policy-Level Implications

Lastly, the findings of this study point to policy-level implications regarding issues of poverty. Five of the participants of this study (Hope, Isabella, Naida, Ruckshana, & Wanika) reported that attending high school in a low-income school district negatively impacted them in college-level mathematics. Attending school in a low-income district was a reported challenge on their pursuit of mathematics-intensive college degrees and is supported by literature indicating that low-income students have fewer opportunities to attain bachelor’s degrees as compared to their higher-income peers (Engle & Tinto, 2008; Engstrom & Tinto, 2010; Thayer, 2000; Tinto, 2007).

One way in which the participants reported that their low-income high schools left them disadvantaged compared to their peers was in their schools’ course offerings. As mentioned previously, the school district of the participants of this study stopped offering algebra in middle school. With all students taking algebra 1 in ninth grade, there is a small opportunity for these students to take calculus in high school. The only chance that a student in this situation would take calculus in high school would be if the student doubles-up on mathematics one year. Many would argue that the only opportunity for doubling-up in high school is with geometry and algebra 2, which would need to occur during the student’s sophomore year of high school. This situation dictates that a student would need to recognize and decide as a ninth grader that their future would benefit from the decision for them to double-up on
mathematics. In a school district with such a high number of first-generation-college students, I conjecture that few students are equipped with the foresight to make this decision as ninth graders. This situation could leave them disadvantaged in college mathematics as compared to their peers from more affluent school districts, who likely had the opportunity to take calculus. That the participants of this study had less opportunity to take high-level high school mathematics courses is not a unique finding to this study; the National Center for Education Statistics (2005) found that underrepresented students took higher-level high school mathematics courses at a lower rate than their non-underrepresented peers. Engle and Tinto (2008) recommended that underrepresented students need “more information and counseling about gateway courses before high school” because “taking a rigorous high school curriculum, including advanced mathematics, greatly increases the chances that low-income and first-generation students will attend college” (p. 3). When making decisions regarding course offerings, policymakers need to be mindful of the negative impact this may have on underrepresented students’ future degree completion, particularly in mathematics.

Finally, policymakers should be mindful that low-income districts may not have the resources to supply students with graphing calculators. Three participants of this study (Isabella, Ruckshana, & Victor) all attributed difficulties in college mathematics courses to their struggles with using a graphing calculator. My interpretation from their interviews was that college professors assumed graphing calculator fluency to be prerequisite knowledge. Perhaps policymakers should prioritize allocating funds to supply low-income districts with graphing calculators.
Limitations

The participants who were selected for this study represent an exemplary, mathematically-inclined group of underrepresented students in that they were mathematics-intending and in that they had received extra mathematics support through their UBMS participation. Consequently, they do not represent a generalizable subset of all underrepresented college freshmen. This also means that I likely did not capture a comprehensive list of all factors that would contribute to the mathematics identities of underrepresented students. There are likely factors that a less-mathematically-inclined cohort of students would experience that were not relevant for the participants of this study. An underrepresented college freshman who did not have the same opportunity as the participants of this study to develop a positive mathematics identity in high school would likely have a different experience in college-level mathematics. The same goes for an underrepresented college freshman enrolled in general education mathematics courses who is not interested in pursuing a mathematics-intensive degree. Consequently, given that the participants were an exemplary group dictates that the results of this study are not generalizable to the entire population of underrepresented college freshmen. Despite this, we do gain important insight when investigating the college experiences of an exemplary group of underrepresented freshmen because it is likely that their struggles would be the struggles of many other underrepresented students.

A second limitation of this study is that I primarily collected data only on the participants’ experiences in college mathematics and did not take into account their experiences in other college courses. For this reason, it is possible that some of the factors contributing to mathematics identity are not unique to mathematics courses. For instance, this study found that working collaboratively in mathematics benefitted
the participants’ mathematics identities. It is possible that collaboration would be beneficial in all college courses and that this finding is not unique to college mathematics courses. However, I did not collect data on the participants’ experiences in other courses, and thus I do not have basis for comparison. With the data I collected, I can make claims on factors that were beneficial (and detrimental) to the participants’ mathematics identities, but I cannot claim that these factors are unique to mathematics.

Lastly, when analyzing mathematics identity change, the data analysis methods of this study did not enable me to make claims about the magnitude of the changes reported by the participants (in other words, a small change versus a large change). At this phase, I recognized that it may have been beneficial to note which changes in identity were major and which were minor. Upon this realization, I attempted to make such claims but I found that I was unable to do so with the present data following the present methods. To ameliorate this, I attempted to avoid oversimplifying the data as a “positive change” or “negative change” and I, instead, provide evidence to demonstrate the change that was present. At times, primarily when presenting the results in table form (e.g. Table 5 and Table 8), it was difficult to avoid an oversimplification of the results as binary (e.g. change or no change, positive change or negative change, etc.). I recognize that future studies would benefit from the implementation of analytic methods to capture magnitude of change. I would encourage readers interested in pursuing this work to consider studies implementing discourse analysis (e.g. Sfard & Prusak, 2005) as inspiration for developing analytic procedures to capture magnitude of change.
Future Research

This exploratory study inspired ideas for two future studies which will continue to examine the recruitment and retention of underrepresented students in postsecondary mathematics. The results of this study shed light on some of the mechanisms of support that are in place for underrepresented students in postsecondary mathematics. I plan to design a future study to develop a comprehensive and implementable list of these mechanisms. To do so, I will identify universities that have high success rates in awarding mathematics-intensive degrees to underrepresented students. This mixed-methods study will seek to develop a model of support that can be applied across institutions. Quantitative data will include information on underrepresented students’ college enrollment, course-taking, grades, degree attainment, and a factors-of-support survey. Qualitative data will include communication with underrepresented graduates of these institutions, professors, and university administrators. By bringing to light factors that are already in place at universities that are successful in graduating underrepresented students in mathematics-intensive fields, less-successful universities can find inspiration in feasible mechanisms of support.

The data sources for this study were reflective student self-report interviews. After conducting this study, I am interested in learning how underrepresented students engage with college mathematics in real-time. To do so, I plan to conduct an ethnographic study in which I shadow underrepresented students for an entire semester while they are working on college-level mathematics. In a well-known study inspired by the desire to investigate the high number of students failing college calculus, Treisman (1992) found that students’ study habits were often linked to their racial background (with Asian students tending to study collaboratively and African
American students tending to work in isolation). As an ethnographic study, capturing the lives of college mathematics students inside and outside of the classroom, my study will extend beyond the participants’ study habits. I will use the data to make two major comparisons. First, I will compare the college mathematics experience of underrepresented students with the experience of non-underrepresented students at the same institution. Next, I will compare underrepresented students at one institution to underrepresented students at another institution. Ideally, I will be able to compare students from institutions that are more successful in awarding mathematics degrees to underrepresented students to schools that are less successful. This study will provide rich findings to improve the retention rate of underrepresented students in college mathematics.

**Conclusion**

This exploratory study provides insight into the lived first-year-college experience of an important group of underrepresented students. The study began with a cohort of underrepresented students who, against the odds, were choosing to pursue mathematics-intensive career paths. Now, this study revealed what happened during their freshman year of college to support or hinder them on this path. In doing so, the study addressed an important national concern: the population growth is projected to be greatest among population groups that have historically been given the least opportunity to succeed in mathematics (Prescott & Bransberger, 2012), yet mathematics-intensive fields have available positions (Curtin & Cahalan, 2004; Engle & Tinto, 2008; Gandara & Bial, 2001; Laguardia, 1998). This exploratory study turned to an exemplary cohort of mathematically-inclined underrepresented participants to better understand the experiences of these students on their path to
mathematics-intensive degrees. The methods employed afforded the unique opportunity to investigate identity change at this crucial time point in a student’s educational trajectory.

A major contribution of this study is that it highlighted the participants’ reported experiences in high school mathematics that were perceived as inadequate in comparison to the expectations in college mathematics. The study was exploratory in nature in that it investigated changes to mathematics identity through the comparison of two data sets at distinct time points. The participants all attended high school in the same low-income urban school district, and they all reported that different aspects of their high school mathematics education negatively impacted them in college mathematics. This impact includes their belief that their high school study skills were inadequate for success in college mathematics, their perception that they were less prepared academically than their non-underrepresented peers, the inferior course offerings as compared to their peers, and their lack of experience with using graphing calculators. The participants also reported that attending school in a low-income district had a greater negative impact on their mathematics identities than any other qualifier for underrepresentation (race/ethnicity, gender, or first-language). These findings provide evidence that teachers, researchers, and policymakers should focus particular attention on low-income students when attempting to address the problem of recruitment and retention of underrepresented students in mathematics-intensive fields.

In addition, this study provides substantial evidence pointing to the benefits of college support programs for underrepresented students. Although the benefits of college support programs have been widely documented (e.g. Engstrom & Tinto,
2010; Moreno et al., 1999; Thayer, 2000, Tinto, 1987), this study is unique in the comparisons that can be made between participants. For one, all of the participants attended high school in the same district and attended the same math/science college outreach program during their high school summers (where they took the same courses). For this reason, the participants all had similar preparation for college. With such similar backgrounds entering college, the benefits experienced by the participants who were members of a college support program over those who were not members are magnified. In addition, the two non-college-support-members attended the same college alongside one of the college support members. The striking difference in mathematics experiences between the member as compared to the non-members at the same institution also magnifies the benefits of membership in such programs. Of course, a qualitative study, particularly with a small number of participants, is not designed to make generalizations to the whole population; the comparisons are of theoretical nature. However, given the nature of the relationship of the participants to each other coupled with the cut-and-dry differences in the mathematics experiences between the members and the non-members makes the benefits of college support programs difficult to ignore.

Above all else, the greatest finding that emerged from this exploratory study was a better understanding of why underrepresented students switch out of mathematics-intensive majors. A richer understanding of this problem was achieved through an investigation of identity change. Quantitative findings (e.g. Engle and Tinto, 2008) have shown us that underrepresented students are completing proportionally fewer mathematics-intensive bachelor’s degrees than their non-underrepresented peers, but we did not have a firm understanding of why this is the
case. This study revealed that for the participants who switched their major, college-level mathematics courses taken during the first year played a major role in their decision; all three students who switched to a non-mathematics-intensive major indicated that mathematics was a pivotal factor in their decision. Further, despite being mathematically-inclined students who were mathematics-intending and had received extra support in mathematics, five of the participants reported that they experienced a decrease in their feeling of competence in mathematics in college. The pivotal role that mathematics courses played in the path to degree completion for these participants reveals that the recruitment and retention of underrepresented students in postsecondary mathematics is a shared problem of mathematicians and mathematics educators, at both the high school level and college level, and all parties must work together to address this national concern.
REFERENCES


Appendix A

INTERVIEW PROTOCOLS

INTERVIEW 1

*Interview 1, Part A: Introductory questions*

If you recall, we spoke twice last year during your senior year of high school. During this interview I’m interested in learning about the ways in which your feelings and beliefs about mathematics have stayed the same or changed. I’m also interested about hearing the reasons behind any changes that occurred. Do you have any questions for me before we start the interview?

- What college are you attending?
- How is college going so far?
- Is it similar to or different from what you thought it would be? In what ways?
- Has your view or opinion of college changed at all over the past year? If so, in what ways?

*Interview 1, Part B: Discussion of narrative*

Recall that after the first time we spoke last year, I took the information you told me about your experiences with mathematics and I typed a narrative. At the start of our second meeting, I showed you the narrative and allowed you to add to it, delete false information, or make corrections. Here is a copy of the narrative that resulted after you were able to make changes [hand a copy of the narrative to the participant]. What I’d like you to do now is read this narrative very carefully. While you’re reading, I’d like you to identify the ways in which you’ve changed since your senior year of high school and the ways in which you’ve stayed the same. You can write on it or take notes if it helps you [hand a pen, highlighter, and blank sheet of paper to the participant]. Once you’re finished reading, let me know and we can talk about the similarities and differences. Once participant is finished reading, ask:

- As you think of your freshman year of college and how this year has shaped who you are, what strikes you in this narrative?
  - Does anything in this narrative capture your eyes?
  - Does anything surprise you?
- Now let’s talk specifically about the differences you see. In what ways are you different from what is stated in this narrative from last year?
  - For each difference, ask:
    - Can you think of any reasons for why this change occurred?
• Continue asking about differences until the participant cannot identify any more

• Now let’s talk about the similarities. In what ways are you the same as stated in this narrative from last year?
  o Continue asking about similarities until the participant cannot identify any more

• If the participant does not cite many similarities or differences, consider going sentence-by-sentence through the narrative.

• Can you think of any other ways in which your feelings or beliefs about math have changed since last year, even if it wasn’t mentioned in the narrative?
  o For each change, ask:
    ▪ Can you think of any reasons for why this change occurred?
  o Continue asking about changes until the participant cannot identify any more

Interview 1, Part C: Major/career plans
[Note: Answers to some of these questions may have emerged during Part 1.]

Last year you told me that you are interested in majoring in _______________ and pursuing a career as a _______________. I’m interested in hearing about whether this is still your plan.

• What are you currently majoring in (or planning to major in)?
  o Why are you interested in this major?
  o How certain are you that you will keep this major?
  o If different from senior-year major, ask:
    ▪ What has caused you to change your major?
    ▪ Has anything else caused you to change your major (continue to ask this until participant cannot identify anything else)?

  o If same as senior year major, ask:
    ▪ What has supported you in continuing to pursue this major?
    ▪ Has anything else supported you in continuing to pursue this major (continue to ask this until participant cannot identify anything else)?

• What are you currently planning to pursue as a career?
  o Why are you interested in this career?
  o If different from senior-year career plan, ask:
    ▪ What has caused you to change your career plan?
    ▪ Has anything else caused you to change your career plan (continue to ask this until participant cannot identify anything else)?

  o If same as senior year career plan, ask:
    ▪ What has supported you in continuing to pursue this career plan?
Has anything else supported you in continuing to pursue this career plan (continue to ask this until participant cannot identify anything else)?

**Interview 1, Part D: Questions about underrepresented status**

[Direct questions about underrepresented status: Ask each participant all of the following questions that are relevant to their underrepresented status.]

- How has being a first generation college student shaped your experience in college mathematics, if at all?
- How has being female shaped your experience in college mathematics, if at all?
- How has being an English language learner shaped your experience in college mathematics, if at all?
- How has being [Hispanic or African American] shaped your experience in college mathematics, if at all?
- How has being classified as low-income shaped your experience in college mathematics, if at all?

**Interview 1, Part E: Closing questions**

- Is there anything else you would like to tell me about how you’ve changed since last year or your plans for the future?
- Do you have any questions for me?
- (((Ask participant to email a copy of their college transcript before the next interview)))
- (((If possible, schedule next interview)))

**INTERVIEW 2**

**Interview 2, Part A: Introductory question**

Last time we met, we spoke about the ways in which you’ve changed since last year. We also talked about your future plans with math.

- Is there anything you thought of since our last meeting that you would like to talk to me about?

Today we will be talking specifically about your experiences with math in college. We’re going to start by going through your transcript.

**Interview 2, Part B: College math courses**

- What math courses have you taken so far in college (use printed copy of transcript to cross-reference this)?
  - Then, for each course, ask:
    - Can you describe your overall experience with this class?
    - Why did you take this class?
What grade did you receive in this course (use printed copy of transcript to cross-reference this)?
Are you happy with this grade?
Why do you believe you received this grade?
Do you feel that your previous math knowledge and experiences adequately prepared you for this course? If so, in what ways and if not, why not?
How did this course contribute to...
- your enjoyment of math?
- your interest in math?
- your belief that math is useful?
- your desire to continue studying math?
- your desire to pursue a math-related career?
- your belief that you can succeed in college-level math?
- your belief that success in math is important for your future success?
- your belief that you can succeed in a math-related career?
Did you feel a sense of belonging in this math class? How or how not?
How was this course similar to or different from your past (pre-college) math courses? How do you feel about these similarities/differences?
- Overall, what do you think about your college math classes?
- Are you planning to take any additional math classes in college? Why or why not? Which ones?

Interview 2, Part C: Other college experiences
Now I’d like to find out more about your college experience outside of class.
- Can you think of anything outside of your math classes that has impacted your feelings about math?
- Are you involved in any sports, clubs, support programs, or activities?
  - For each activity ask:
    - What has your experience been like with this activity?
    - Has this activity supported you in following your career path?
- Are you involved in any academic groups or programs, such as Student Support Services, the Society of Black Engineers, or any other programs such as these?
  - For each program ask:
    - What has your experience been like with this program?
    - Has this program supported you in following your career path?
Interview 2, Part D: The role of college outreach
A big part of why I asked you to participate in my study is because you had a unique experience of participating in UBMS, a college-outreach program designed to help students succeed in math and science majors and careers.

- **If the student has already mentioned UBMS in the interview, ask:**
  - So far you mentioned that UBMS [helped you/didn’t help you] by _____.
    - Can you think of any [other] ways in which UBMS helped to prepare you for college?
    - Can you think of any [other] ways in which UBMS helped to prepare you for college math specifically?
- **If the student did not mention UBMS in the interview, ask:**
  - I noticed you did not mention UBMS in this interview yet.
    - Is there a reason why you have not mentioned UBMS?
    - Can you think of any ways in which UBMS helped to prepare you for college?
    - Can you think of any ways in which UBMS helped to prepare you for college math specifically?
- Do you notice any similarities or differences between your UBMS math classes and your college math classes? How do you feel about these [similarities/differences]?
- Can you think of any ways in which UBMS could have better prepared you for college or college math?

Interview 2, Part E: Closing questions
- Is there anything else you would like to tell me about your experience with college math?
- Do you have any questions for me?

INTERVIEW 3
The protocol for the third interview was personalized for each participant based on their responses during the first two interviews. I am providing sample interview questions for the types of questions that I asked.

- When we spoke last year, you had mostly positive things to say about your experiences with mathematics through high school. I noticed that this year, you also seem to be feeling positive about your college math experience. Can you think of anything you’ve experienced over the past year that has helped to support you in college mathematics? OR When we spoke last year, you had mostly positive things to say about your experiences with mathematics through high school. I noticed that this year, you seem to be feeling less-positive about
your college math experience. Can you think of anything you’ve experienced over the past year that has had a negative impact on your experience in mathematics?

- Even though you’ve had a mostly-positive experience in college math, can you think of anything you’ve experienced over the past year that has had a negative impact on your experience in mathematics? OR Even though you’ve had a mostly-negative experience in college math, can you think of anything you’ve experienced over the past year that has had a positive impact on your experience in mathematics?

- Can you think of anything that could have provided additional support for you in college math? [Continue asking until participant cannot think of anything else]

- [Question will vary for each participant:] During our last meeting, you mentioned that you often work with peers in your college math classes. When you were in high school, you told me that you never work with peers. Can you explain why this change occurred?

- [Question will vary for each participant:] During our last meeting, you mentioned that your confidence in math has decreased this year. Can you speak more about why you think this is?
Appendix B

SAMPLE NARRATIVE

SAMPLE NARRATIVE (TIMOTHY)
Directions to participant: The paragraphs below contain what I learned from speaking with you the first time. Please read this and let me know whether it rings true to you or whether you want to revise it. Feel free to let me know if there is anything that needs to be changed, added, or removed. I want to be certain that I am representing you accurately.

During the school year, Timothy often finds that he is ahead of his classmates in math. This makes it difficult for him to enjoy math in the same way that he does during the summer when he’s surrounded by other UBMS students who share similar talents in math. He and his UBMS classmates are able to have friendly competitions with each other and this challenge is what makes him enjoy math more in the summer than during the year. He also feels that UBMS provided a friendlier environment in which to learn math. During the school year he sometimes hesitates to ask questions in class. This is unlike how he feels in UBMS classes when he actually wants to participate. The closeness he feels with his UBMS peers helps him to feel more comfortable in class.

Despite his present talent for math, Timothy surprisingly did not always enjoy it. Before Upward Bound he used to have difficulty in math and his mind used to go blank sometimes. Once he joined UBMS and started getting previews of his math courses, he started understanding it and this contributed to him enjoying it more. He has also seen his grades improve; before UBMS he was getting C’s in math and now he gets A’s. In Timothy’s words, “if it wasn't for Upward Bound I probably wouldn't even like math now.” Once UBMS helped Timothy to start enjoying math more, he also started realizing that math was interesting because it is useful in different jobs. He used to wonder about the uses of the math he was learning in school, but now that he’s in calculus he sees that math is used for different real applications.

Timothy plans on majoring in biology with the goal of someday become a veterinarian. He realizes that he will need to take quite a few math courses in college to accomplish this goal and he believes that he has the strong math and science background to be able to take-on these classes. In his words, “I'll be able to pursue that without a problem.” However, Timothy did not always have this confidence. He always had an interest in biology as a major but he didn’t know if he would be able to do the work. That changed when he began participating in UBMS and started realizing his talents in math and science. Not only does Timothy feel that he will be
successful in his required math courses in college, but he also plans to take extra math classes!

Timothy summarized his own relationship with math when he wrote that he “was not good at math at first, but he slowly developed the skills needed to make a successful career out of math...Despite his rough beginning with math, [he] feels that math is his strong point now and is ready to succeed in mathematics.”
Appendix C

INSTITUTIONAL DEMOGRAPHICS

This appendix contains institutional demographic data for the colleges attended by the participants of this study. I also provide overall demographic data for the state housing the four colleges and demographic data for the relevant departments within the colleges, when available. The included departments are based on the participants’ starting college majors because these were the departments in which they would have taken courses during their first year. I obtained the data from a variety of sources including state department of education web sites, university web sites, consumer report web sites, and direct communication with college personnel (faculty and administrative assistants). According to the IRB documents for this study, I cannot reveal the names or locations of the participants’ colleges. Thus, the sources cannot be provided. Additionally, data was altered slightly as to maintain the general composition of the colleges while also protecting the colleges’ identities.

STATE:

Demographics of the state (2013-2013 public school enrollment):
Male = 51%  White/Caucasian = 50%
Female = 49%  Black/African American = 16%
                      Hispanic/Latin(o/a) = 23%
                      American Indian/Native American/Alaska Native = <1%
                      Asian = 9%
                      Hawaiian Native/Pacific Islander = <1%
                      Two or more races = 1%

COLLEGES/UNIVERSITITES:

Demographics of Large Research University (2013-2014 academic year):
(attended by Ruckshana, Timothy, & Wanika)
Male = 51%  White/Caucasian = 45%
Female = 49%  Black/African American = 7%
                      Hispanic/Latin(o/a) = 12%
                      Asian = 27%

Demographics of Suburban Public College (Fall 2013):
(attended by Hope & Isabella)
Male = 43%  White/Caucasian = 66%

Female = 57%  Black/African American = 5%
Hispanic/Latin(o/a) = 11%
American Indian/Native American/Alaska Native = <1%
Asian = 9%
Hawaiian Native/Pacific Islander = <1%
Two or more races = 1%

Demographics of Mid-Size Teaching University (Fall 2014):
(attended by Naida)
Male = 39%  White/Caucasian = 50%
Female = 61%  Black/African American = 11%
Hispanic/Latin(o/a) = 27%
American Indian/Native American/Alaska Native = <1%
Asian = 6%
Hawaiian Native/Pacific Islander = <1%
Two or more races = 4%

Demographics of Small Liberal Arts College (Fall 2013):
(attended by Victor)
Male = 49%  White/Caucasian = 66%
Female = 51%  Black/African American = 8%
Hispanic/Latin(o/a) = 15%
American Indian/Native American/Alaska Native = <1%
Asian = 7%
Hawaiian Native/Pacific Islander = <1%
Two or more races = 1%

DEPARTMENTS WITHIN COLLEGES/UNIVERSITIES:

Demographics of Large Research University, Engineering Department (Fall 2013):
(housing Ruckshana as a biomedical engineering major)
Male = 77%  White/Caucasian = 37%
Female = 23%  Black/African American = 6%
Hispanic/Latin(o/a) = 9%
Asian = 32%

Demographics of Large Research University, Biology Department (Fall 2014):
(housing Timothy and Wanika as biology majors)
Male = 40%  White/Caucasian = 56%
Female = 60%  Minority = 44%

Demographics of Suburban Public College, Mathematics Department (Spring 2015):
Demographics of Suburban Public College, Biology Department:
(housing Hope as a biology major)
Male = 38%  White/Caucasian = 38%
Female = 62%  Black/African American = 6%
  Hispanic/Latin(o/a) = 11%
  American Indian/Native American/Alaska Native = <1%
  Asian = 38%
  Two or more races = 1%

Demographics of Mid-Size Teaching University, Business Department:
(housing Naida as a business major)
Demographic data not reported

Demographics of Small Liberal Arts College, Business Department:
(housing Victor as an accounting major)
Demographic data not reported
Appendix D

IRB APPROVAL LETTER

DATE: May 15, 2014

TO: Alison Marzocchi
FROM: University of Delaware IRB

STUDY TITLE: [589036-1] Factors Contributing to Underrepresented Students’ Mathematics Identities after their First Year in College

SUBMISSION TYPE: New Project

ACTION: APPROVED
APPROVAL DATE: May 15, 2014
EXPIRATION DATE: May 14, 2015
REVIEW TYPE: Expedited Review
REVIEW CATEGORY: Expedited review category # (6,7)

Thank you for your submission of New Project materials for this research study. The University of Delaware IRB has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a study design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

This submission has received Expedited Review based on the applicable federal regulation.

Please remember that informed consent is a process beginning with a description of the study and insurance of participant understanding followed by a signed consent form. Informed consent must continue throughout the study via a dialogue between the researcher and research participant. Federal
regulations require each participant receive a copy of the signed consent document.

Please note that any revision to previously approved materials must be approved by this office prior to initiation. Please use the appropriate revision forms for this procedure.

All SERIOUS and UNEXPECTED adverse events must be reported to this office. Please use the appropriate adverse event forms for this procedure. All sponsor reporting requirements should also be followed.

Please report all NON-COMPLIANCE issues or COMPLAINTS regarding this study to this office.

Please note that all research records must be retained for a minimum of three years.

Based on the risks, this project requires Continuing Review by this office on an annual basis. Please use the appropriate renewal forms for this procedure.

If you have any questions, please contact Nicole Farnese-McFarlane at (302) 831-1119 or nicolefm@udel.edu. Please include your study title and reference number in all correspondence with this office.