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Underrepresented Students Pursuing Mathematics-Intensive Degrees: Changes After Transitioning to College

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Abstract

This longitudinal qualitative study followed a cohort of mathematics-intending underrepresented students from their senior year of high school into their freshman year of college to identify changes on their path to mathematics-intensive degree attainment. The study was driven by an overarching goal of improving 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, the study was focused on mathematics identity development. Hence, the research questions guiding this study were (1) *How do underrepresented college freshmen describe their mathematics identities?* and (2) *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?* 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, 2014) to examine whether their mathematics identities had changed over time. Results indicated that four of the seven participants persisted on their degree path while the remaining three switched to less-mathematics-intensive programs. As participants were interviewed shortly after completion of their freshman year of college, this study provides important information on challenges encountered by mathematically-inclined underrepresented students during that crucial year. Some of the challenges include difficulties in learning study skills for college-level courses, feeling unskilled in graphing calculator usage, and feeling underprepared for college-level mathematics as compared to their peers.

Keywords: college transition, underrepresented students, mathematics education, college mathematics, postsecondary mathematics

Underrepresented Students Pursuing Mathematics-Intensive Degrees: Changes After Transitioning to College

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, as an African American male who attended public school in a low-income district, statistics indicate that Victor has been given less opportunity to complete a bachelor's degree as compared to his peers.

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 want to take [math] 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 anymore." 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, Victor 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 high school have better prepared him for the challenges of college-level mathematics? 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? Questions such as these will be examined in this study.*

It is because of Victor and his peers that this research program focuses on examining the recruitment and retention of underrepresented students in postsecondary mathematics. This study was designed 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 study provides 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.

This study focuses upon underrepresented students 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 which 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). A low-income student is defined in this study 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 at the time of participant recruitment). 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.

As a means to encourage more underrepresented students to continue postsecondary study of mathematics, this study focuses on mathematics identity development. This study built upon the findings from a previous study (Marzocchi, 2014) which investigated the mathematics identity development of the same cohort of participants. 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 several ways. The benefits include a sustained interest in mathematics (Berry, Thunder, & McClain, 2011), increased engagement with mathematics (Jilk, 2014), and mathematical proficiency (Larnell, 2013). It was conjectured that these benefits of fostering positive mathematics identities could help to improve the recruitment and retention of underrepresented students in postsecondary mathematics.

The primary research questions that were addressed in this study were (1) *How do underrepresented college freshmen describe their mathematics identities?* and (2) *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.

Literature Review

Researchers and policymakers express concern over the diminishing number of students choosing to continue their study of mathematics (Boaler & Greeno, 2000; 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). The shortage of qualified graduates pursing 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; Curtin & Cahalan, 2004; Engle & Tinto, 2008; Gandara & Bial, 2001; Howard, 2003; Thayer, 2000; Treisman, 1992). 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).

A Focus on Underrepresented Students

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). Engle and Tinto (2008), who wrote a report examining the college experience of low-income and first-generation-college students, 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). These authors found that students who are low-income and first-generation-college are at the greatest risk of failure in postsecondary education.

A Focus on Mathematics Identity Development

As a means of encouraging more underrepresented students to continue postsecondary study of mathematics, this study focuses on mathematics identity development. Berry et al. (2011) found that the development of a positive mathematics identity leads to sustained interest in and persistence with mathematics. 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.

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 a previous study (Marzocchi, 2014).

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) (see Figure 2).

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. The inherently social aspects of learning mathematics in a college environment made it important to include Wenger's (1998) social theory of identity in this 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.

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), as seen in Figure 1. Figure 2 is provided to show which identity components were informed by which theoretical perspective(s).

Methods

This qualitative study built upon findings from a previous study (Marzocchi, 2014) 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. Specifically, the participants of this study were asked to reflect on results from a prior study (Marzocchi, 2014) about their identities as reported a year earlier, 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 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 a previous study (Marzocchi, 2014) 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 1 for demographic information and Table 2 for school information on each participant). The participants were considered 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 1.

Data Collection and Analysis

The data sources for this study were three one-on-one interviews between the author and each of the seven participants, for a total of 21 interviews. 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. 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).

Data for this study consisted of three transcribed interviews with each participant. All coding was done using NVivo[2] 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

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[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.

[2] NVivo qualitative data analysis software; QSR International Pty Ltd. Version 9, 2010.

identities. The first stage of analysis consisted of examining the two sets of codes separately. The second stage of analysis involved using coding sheets generated by NVivo to search for patterns and themes within and across codes. The final stage of analysis made use of matrix coding to unveil sections of a transcript that were double-coded for both a factor and an identity component. Additionally, analytic memos were constructed to track themes that emerged throughout the analyses.

Results

Four of the seven participants persisted on their mathematics-intensive degree paths while the remaining three switched to less-mathematics-intensive programs. All participants, whether they persisted or not, reported that they felt underprepared for college-level mathematics. Several reported other factors, such as having inadequate study skills and feeling unskilled in graphing calculator usage.

Changes in 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). The *Who do I want to be?* and *Who can I be?* questions in the model of mathematics identity (see Figure 1) can be used to investigate this situation. The *Who do I want to be?* question of mathematics identity is addressed by the *desire to continue studying mathematics* and the *desire to pursue a mathematics-intensive career* components. These components were intertwined with the *feeling the potential to succeed in college-level mathematics* and the *feeling the potential to succeed in a mathematics-intensive career* components which contribute to the *Who can I be?* question of mathematics identity.

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 3.

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.
>
> 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 [general education] math so right now I'd be done with math. I know for accounting I need to take more math classes in the future.
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> 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.

Factors Contributing to Changes in Mathematics Identity

Although the participants spoke of many factors which contributed, both positively and negatively, to their mathematics identities (see Table 4), this paper will focus only on the factors which were categorized as "high school to college comparison factors." This decision was made because these are the factors which deal most directly with the transition from high school to college mathematics. The high school to college comparison factors include 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. Each of these factors contributed negatively to the mathematics identities of the participants who reported experiencing them.

Believing that high school study skills are inadequate for success in college mathematics. Five participants reported a need to change their study habits between high school and college (Isabella, Naida, Ruckshana, Timothy, & Victor). They reported that the study skills required for success in their high school mathematics courses were inadequate for success in college mathematics. Several participants discussed the difference between their study habits in college as compared to high school. For instance:

> 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.
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> 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 the participants of this study were among the top students in their high school, particularly in mathematics and science. Their statements reveal a belief that being good at mathematics in high school meant that they did not need to do much studying.

Feeling unskilled in graphing calculator usage. Three participants (Isabella, Ruckshana, & Victor) reported that using a graphing calculator was a source of difficulty for them in college mathematics. 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.
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> 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.
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> 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.

After uncovering this finding, follow-up data was collected from each participant on their graphing calculator usage in high school. Each participant reported to have contact with a graphing calculator for fewer than 20 mathematics lessons throughout their entire high school career. Anecdotal evidence from the author indicated that calculators were fluently integrated into the curriculum in a middle-income district and an affluent district at which she was a teacher and student, respectively. Thus, it was conjectured 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, there was a sense that their college mathematics professors expected that graphing calculator fluency was a prerequisite skill for college mathematics courses. As 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 less prepared for college-level mathematics as compared to peers. All seven participants reported that they felt underprepared for college-level mathematics. 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 was selected as a student case because she spoke of feeling unprepared for college generally, as well as feeling unprepared for mathematics specifically. Recall that Naida dropped her mathematics-intensive majors. 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…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.

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. 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.

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. 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.

Discussion

This study investigated the retention of mathematically-inclined underrepresented students as they pursued mathematics-intensive degrees during their first year of college. The participants of this study are low-income and/or first-generation-college which dictates that they will likely face a unique set of challenges in their transition to college-level mathematics. 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).

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 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. 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 degree 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.

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; Nasir, 2002; National Center for Education Statistics, 2005; Thayer, 2000; Tinto, 2007; Treisman, 1992; Tyson et al., 2007). 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 a prior study (Marzocchi, 2014) indicated that the participants were more likely to disengage with the courses that they perceived to be too easy, 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. It is important for colleges to provide support to students in need and to make students aware of this support (Engstrom & Tinto, 2010). Students who are in need of the support should be encouraged to attend by faculty and advisors. 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, stating "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).

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.

Conclusion

This 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). 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 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 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, their lack of experience with using graphing calculators.

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. 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. 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

Appleby, J., & Cox, W. (2002). The transition to higher education. In P. Kahn & J. Kyle (Eds.), *Effective learning and teaching in mathematics and its applications*. Sterling, VA: Stylus Publishing Inc.

Beach, K. (1999). Consequential transitions: A sociocultural expedition beyond transfer in education. *Review of Research in Education*, *24*, 101-139.

Berry, R. Q., Thunder, K., & McClain, O. L. (2011). Counter narratives: Examining the mathematics and racial identities of Black boys who are successful with school mathematics. *Journal of African American Males in Education, 2*(1), 10-23.

Boaler, J., & Greeno, J. (2000). Identity, agency, and knowing in mathematics worlds. In J. Boaler (Ed.), *Multiple perspectives on mathematics teaching and learning* (pp. 171-200). Westport, CT: Ablex Publishing.

Cruce, T. M., Kinzie, J. L., Williams, J. M., Morelon, C. L., & Xingming, Y. (November 2005). *The Relationship between First-Generation Status and Academic Self-efficacy among Entering College Students.* Paper presented at the 30th Annual Meeting of the Association for the Study of Higher Education (ASHE). Philadelphia, PA.

Curtin, T. R., & Cahalan, M. W. (2004). *A profile of the Upward Bound Math-Science Program: 2000-2001*. Washington, DC.

Engle, J., & Tinto, V. (2008). *Moving beyond access: College success for low-income, first-generation students*. Washington, DC.

Engstrom, C., & Tinto, V. (2010). Access without support is not opportunity. *Change: The Magazine of Higher Learning, 40*(1), 46-50.

Gandara, P. C., & Bial, D. (2001). *Paving the way to postsecondary education: K-12 intervention programs for underrepresented youth*. Washington, DC.

Gholson, M. (April 2013). *The Collective Mind: At the Many Intersections of Race, Black Learners, and Identity in Mathematics Education*. Paper presented at the National Council of Teachers of Mathematics Research Presession, Denver, CO.

Herbers, J. E., Cutuli, J. J., Lafavor, T. L., Vrieze, D., Leibel, C., Obradovic, J., & Masten, A. S. (2011). Direct and indirect effects of parenting on academic functioning of young homeless children. *Early Education and Development, 22*, 77-104.

Howard, T. C. (2003). "A tug of war for our minds": African American high school students' perceptions of their academic identities and college aspirations. *The High School Journal*, *87*(1), 4-17.

Jay, G. M., & D'Augelli, A. R. (1991). Social support and adjustment to university life: A comparison of African-American and White freshmen. *Journal of Community Psychology*, *19*, 95-108.

Jilk, L. M. (2014). "Everybody can be somebody": Expanding and valorizing secondary school mathematics practices to support engagement and success. In N.S. Nasir, C. Cabana, B. Shreve, E. Woodbury, & N. Louie (Eds.), *Mathematics for equity: A framework for successful practice* (pp. 107-125). New York, NY: Teachers College Press.

Jordan, N. C., & Levine, S. C. (2009). Socioeconomic variation, number competence, and mathematics learning difficulties in young children. *Developmental Disabilities Research Reviews, 15*, 60-68.

Kilpatrick, J., Swafford, J., & Findell, B. (2001). *Adding it up: Helping children learn mathematics.* Washington, DC: National Academy Press.

Larnell, G. V. (2013). On "new waves" in mathematics education research: Identity, power, and the mathematics learning experiences of all children. *New Waves-Educational Research & Development*, *16*(1), 146-156.

Marzocchi, A. S. (2014 April). *The Development of Underrepresented Students' Mathematics Identities*. Presentation at the National Council of Teachers of Mathematics Research Conference, New Orleans, LA.

Moreno, S. E., Muller, C., Asera, R., Wyatt, L., & Epperson, J. (1999). Supporting minority mathematics achievement: The Emerging Scholars Program at the University of Texas at Austin. *Journal of Women and Minorities in Science and Engineering*, *5*, 53-66.

Nasir, N. S. (2002). Identity, goals, and learning: Mathematics in cultural practice. *Mathematical Thinking and Learning, 4*, 213-248.

National Center for Education Statistics (2005). *First generation college students in postsecondary education.* Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement.

Polman, J. L., & Miller, D. (2010). Changing stories: Trajectories of identification among African American youth in a science outreach apprenticeship. *American Educational Research Journal*, *47*(4), 879-918.

Powell, A., & Berry, R. Q. (2007). Achieving success: Voices of successful African American mathematics students. In M. C. Brown (Ed.), *Still not equal: Expanding educational opportunity in society* (pp. 167-175). New York, NY: Peter Lang Publishing, Inc.

Prescott, B. T., & Bransberger, P. (2012). Projections of high school graduates. In *Knocking at the college door* (pp. 5-26). Boulder, CO: Western Interstate Commission for Higher Education.

Shah, N., Lewis, C. M., Caires, R., Khan, N., Qureshi, A., Ehsanipour, D., & Gupta, N. (March 2013). *Building Equitable Computer Science Classrooms: Elements of a Teaching Approach*. Proceedings of the 44th ACM Technical Symposium on Computer Science Education. Denver, CO.

Thayer, P. (2000). Retention of students from first-generation and low-income backgrounds. *The Journal of the Council for Opportunity in Education,* 2-9.

Tinto, V. (2007). Research and practice of student retention: What next? *Journal of College Student Retention, 8*(1), 1-19.

Treisman, P. U. (1992). Studying students studying calculus: A look at the lives of minority mathematics students in college. *The College Mathematics Journal, 23*(5), 362-373.

Tyson, W., Lee, R., Borman, K. M., & Hanson, M. A. (2007). Science, technology, engineering, and mathematics (STEM) pathways: High school science and math coursework and postsecondary degree attainment. *Journal of Education for Students Placed at Risk*, *12*(3), 243-270.

Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity.* New York: Cambridge University Press.

Table 1

Description of Participants

Pseudonym	Gender	Race/Ethnicity*	Birth Country*
Hope	Female	Latina/Hispanic	Dominican Republic
Isabella	Female	Hispanic	Dominican Republic
Naida	Female	Hispanic	USA
Ruckshana	Female	Bengali-American	USA
Timothy	Male	Hispanic/Dominican	USA
Victor	Male	African American	USA
Wanika	Female	African American	USA

Pseudonym	First Language*	Low Income?	First Generation?
Hope	Spanish	Yes	Yes
Isabella	Spanish	Yes	No
Naida	English & Spanish	Yes	Yes
Ruckshana	English & Bengali	Yes	Yes
Timothy	English & Spanish	No	Yes
Victor	English	Yes	Yes
Wanika	English	Yes	No

Note. *Race/ethnicity, birth country, and first language were self-reported by participants

Table 2

Participants' Schools

Pseudonym	High School*	College*
Hope	South Street High School	Suburban Public College
Isabella	South Street High School	Suburban Public College
Naida	South Street High School	Mid-Size Teaching University
Ruckshana	North Ridge Park High School	Large Research University
Timothy	Sunny Hill High School	Large Research University
Victor	South Street High School	Small Liberal Arts College
Wanika	Sunny Hill High School	Large Research University

Note. *School names are pseudonyms.

Table 3

Changes in College Major Among Participants

Pseudonym	2013 Findings (high school)	2014 Findings (college)
Naida	Deciding between business and neuroscience	Switched to law
Victor	Deciding between accounting or criminal justice, with a preference for accounting	Leaning towards criminal justice over accounting
Wanika	Planned to major in biology with the intention of becoming a veterinarian	Switched to animal science and dropped the plan of becoming a veterinarian

Table 4

Factors Contributing to Mathematics Identity, as Reported by Participants

Factors	Number of participants	Reported influence on math identity	
		positive	negative
High school to college comparison factors			
Believing that high school study skills are inadequate for success in college mathematics	5		X
Feeling unskilled in graphing calculator usage	3		X
Feeling less prepared for college-level mathematics as compared to their peers	7		X
Factors pertaining to the mathematics professor			
Feeling encouraged to (or discouraged from) participating in class	3	X	X
Perceiving that the professor is willing and available to help	3	X	
Perceived quality of the professor	7	X	X
Outside-of-class support factors			
Working collaboratively with peers	5	X	
Seeking opportunities for help or tutoring	5	X	
Feeling supported by an advisor or role model	5	X	
Participating in a college support program	5	X	
Factors outside of the college			
Family involvement	6	X	X

Note. This table provides an overview of the factors that the participants reported as contributing to their mathematics identities. 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. Table 4 only intends to provide an overarching summary of the factors and their contribution, for the purpose of orienting the reader.

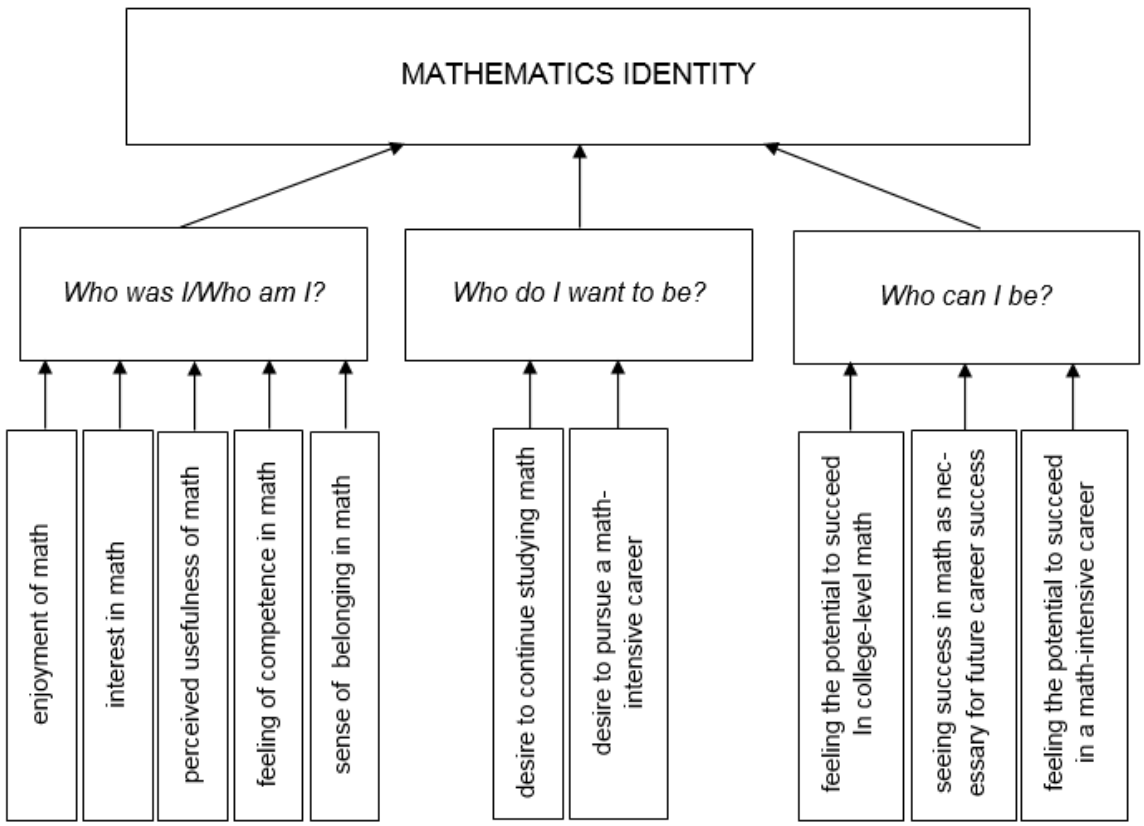

Figure 1. Model of mathematics identity.

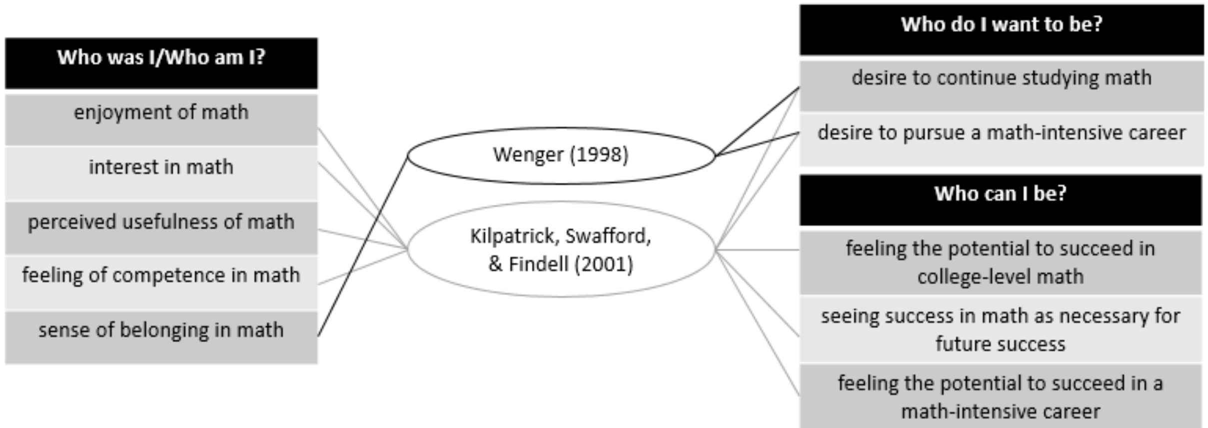

Figure 2. Theoretical perspectives informing the ten components of mathematics identity.