

**PERSISTENCE FACTORS OF GRADUATE MATH STUDENTS
WHO BEGAN COLLEGE IN A REMEDIATED MATH CLASS**

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SIGNATURE PAGE

THESIS: PERSISTENCE FACTORS OF GRADUATE MATH STUDENTS WHO BEGAN COLLEGE IN A REMEDIATED MATH CLASS

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ABSTRACT

Roughly half of students entering college as STEM majors fail to earn a STEM degree, and the number of STEM degree-holders is not enough to meet projected STEM employment. Many STEM students begin college in a remediated classroom and face challenges due to both remediation and STEM coursework. This study follows eight individuals who began in a remediated math class in college, and who were enrolled in, or had already completed, a graduate math program at the time of this study.

Commonalities in their reasons for persistence are investigated. Four themes emerged from the data: (1) Participants either demonstrated early determination (i.e. before College Algebra) or fell into a math degree much later (i.e. Calculus or later) due to circumstances which kept them in the STEM pipeline; (2) review of early math materials due to remedial placement was critical to persistence in the field; (3) support systems including family, friends, cohorts (e.g. study groups), and faculty were vital to persistence; and (4) early math jobs provided repeated exposure to foundational math material and helped students to persist in later math classes.

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CHAPTER 1

INTRODUCTION

Innovations in science and engineering have driven economic growth in the United States over the last five decades. More recently, technology has risen to become a defining driver of productivity in business and industry. In that context, college graduates in science, technology, engineering, and mathematics (STEM) disciplines provide critical talent that fuels America's competitive ability. Unfortunately, the United States is not producing enough STEM specialists, STEM teachers, or STEM-literate citizens to sufficiently drive innovation, spur economic growth, and produce engaged, informed leaders and citizens. New strategies, tactics, and tools are necessary to address the complex STEM workforce demand. (BHEF, 2011)

Two topics of intense interest in education literature today are STEM education and remedial education. While STEM discussions tend to center around the need for trained STEM workers and graduation and attrition rates of STEM majors (Chen, 2009; Chen, 2013; Chen & Ho, 2012; Langdon et al, 2011), discussions about remedial education focus on the number of students requiring remediation, the accuracy of their placement tests, completion rates of remedial sequences, students' success in gatekeeper courses and transfer and degree-attainment rates of remediated students (Adelman, 1999; Attewell et al, 2006; Bailey et al, 2009; Belfield & Crosta, 2012; Bettinger & Long, 2005; Horn & Skomsvold, 2011; Radford & Horn, 2012; Scott-Clayton, 2012; Shapiro & Dundar, 2013; Shapiro & Dundar, 2014; Sparks & Malkus, 2013). Rarely are the topics of STEM education and remediation used in the same sentence. However, a projected increase in STEM jobs along with a projected shortage of STEM workers to fill those jobs (Langdon et al, 2011) calls for new ways of addressing these problems. Perhaps it is time to consider both topics at once.

In California, the University of California system guarantees admission through the Eligibility in the Local Context (ELC) program to the top 9% of public high school graduates¹, and thus it often attracts the best and brightest students in the state. While the University of California system boasts that one-third of its 2011-12 graduates earned a STEM degree (University of California, 2014), it fails to acknowledge the number of STEM majors which were lost through attrition. Nationwide estimates put STEM attrition at four-year universities at about 48% (Chen, 2013). If that same attrition rate applies to the UC system, then roughly half of the “best and brightest” students who attended UC schools and initially declared a STEM major did not complete a STEM degree during that time. Clearly, reducing STEM attrition would be the quickest and most cost-effective way to retain the best and brightest students in STEM disciplines to meet the STEM needs of the country; failing that, alternative methods of recruiting and retaining STEM majors into our educational institutions need to be identified.

While there is a shortage of STEM degree-holders in the United States, in part due to the attrition of STEM students, there is a wealth of another type of student in colleges across America: remediated students. Studies suggest that high numbers of entering students require math remediation (Adelman, 1999; Adelman, 2006; Bailey et al, 2010; Horn & Skomsvold, 2011; Radford & Horn, 2012; Sparks & Malkus, 2013). While one might expect that placement into remediation would prevent students from being interested in STEM degrees, there is reason to believe otherwise. In fact, one study

¹ Eligibility based on the following: California residency, ranking in the top 9% of student’s high school class based on GPA in UC-approved coursework taken during 10th and 11th grades, a minimum GPA of 3.0, and completion of specific a-g coursework prior to senior year.

revealed that approximately 40% of 2003-04 first-year college students who took remediation classes had declared as STEM majors (Sparks & Malkus, 2013).

Some of the difficulties faced by remediated students, in general, are completion of remediation coursework, successful completion of gateway courses, extended time to degree, meeting transfer requirements (for those entering at two-year colleges), and degree completion. The challenge of STEM classes can make the journey to degree for remediated students even more difficult. Additionally, remediated students must overcome the stigma of low expectations that often accompany a remediated background.

If students who successfully complete remediation and a degree are rare, it stands to reason that students who begin in remediation and persist to complete any STEM degree are rarer still. This is perhaps why little is known about such students. The purpose of this study is to begin to fill this gap by studying students who began their college journey in a remediated math class and persisted not only to a STEM degree but to a math degree. Studying their reasons for persistence against overwhelming odds and commonalities across students' experiences is important, for it may help educators better understand how to keep remediated students in the STEM pipeline, open up new ways to mitigate the large attrition rates in today's STEM programs, and better enable universities to understand the potential benefits students may experience from remediation programs.

Thesis Overview

The fascinating stories of students who began in math remediation and persisted to a math degree follow shortly. Specifically, in Chapter 2, we'll take a closer look at the success rates of remediated students, students who transfer from two-year to four-year colleges, and the rate of degree completion among students in STEM programs.

Additionally we'll examine the need for STEM majors in the United States. In Chapter 3, we'll discuss the methodologies employed in the study. Specifically, we begin by considering the reasons why a phenomenological study was warranted. An overview of the methods of data collection and data analysis that were utilized in this study will also be given.

In Chapter 4, two case studies will be presented. These cases exemplify many of the commonalities identified through analyses of the data while providing the reader with a sense of how these commonalities manifest themselves as part of an individual's lived experience. After which, general characteristics are described that are drawn from the analysis of semi-structured interviews with the larger cohort. In Chapter 5, a summary of the findings, limitations of the study, and possible topics for future research are discussed.

CHAPTER 2

BACKGROUND

The issues raised in the previous chapter – remediation, persistence, and STEM degrees – are seemingly unrelated. This study attempts to bridge those issues in order to explore why some remediated students overcome the odds to persist not only to degree, but to a math degree.

Remediation and Persistence

Remedial education, also known as developmental education, is a topic of significant interest among today's educators, and identifying ways to help remediated students persist to degree is one area of particular concern. Data generated from the nationwide 2003-04 Beginning Postsecondary Students Longitudinal Study (BPS:04/09) and its accompanying 2009 Postsecondary Education Transcript Study (PETS:09) which reported the characteristics, persistence and attainment of approximately 19,000 entering college students over the period 2003-09, found that 50.4% of the students had taken at least one remedial course (Radford & Horn, 2012). This is significant because analysis of the National Educational Longitudinal Study of 1988 (NELS:88), which followed the academic achievements of 2 million students from 8th grade until 8.5 years after high school graduation, revealed that while 69% of nonremediated students earned a bachelor's degree, only 39% of remedial reading students and 60% of students who took non-reading remediated classes achieved the same (Adelman, 1999). Many of our remediated students are failing to complete their educational goals, and understanding the reasons for persistence of remediated students, as well as the reasons for their failure to persist, may help educators close the gap between those numbers.

Community Colleges, Two-Year Public Colleges

Using data from the 2003-04 National Postsecondary Student Aid Study (NPSAS:04), which followed 81,000 undergraduates, Sparks & Malkus (2013) showed that about 30% of students reported taking at least one remedial course in their first year of school. However, data from the 2003-04 Federal Beginning Postsecondary Students Longitudinal Study (BPS:04/09), along with its 2009 Postsecondary Education Transcript Study (PETS:09) component, which followed approximately 19,000 first-time college students for a period of 6 years after entering college, painted a bleaker picture. This data showed that 68% of students who entered two-year colleges during the 2003-04 academic year took at least one remedial course during the following 6 years (Radford & Horn, 2012). While those numbers represent all types of remediated courses, a study conducted at colleges in the Achieving the Dream initiative, which is a nationwide, multi-year, data set, found that in a sample of 57 colleges with 250,000 students, 59% of students entering at community colleges were referred to developmental math (Bailey, Jeong, & Cho, 2010).

With so many students being referred to remediation in general, and math remediation in particular, the accuracy of placement tests was examined. Research conducted on over 42,000 students in a large urban community college system in Ohio revealed that two commonly used placement tests severely misplaced roughly 25% of incoming math students and placed them in too high a class – where they failed the course – or severely underplaced them into a remediated class (Belfield & Crosta, 2012; Scott-Clayton, 2012). Misplacing a student into remediation often causes the education process to be extended, at both a financial and time cost to the student.

In addition to this, completion rates for remediated coursework, and completion of a first college-level (gatekeeper) course filter students out of the educational system. Bailey et al (2010) found that only about 33% of community college students referred to remediated math classes completed the sequence of courses, and only 20% passed their gatekeeper math course within three years. Additionally they found that “developmental education completion rates are negatively related to the number of levels to which a student is referred” (p. 259). Their research also showed that 45% of students referred to one developmental class completed their developmental track; 32% assigned to two levels of remedial math completed the track; and only 17% of students assigned to three classes of remedial math completed their developmental education.

Because remediation increases the number of classes required to graduate, it also extends the time to degree for students, and therefore “may negatively impact student outcomes such as persistence” (Bettinger & Long, p.1, 2005). This negative impact on persistence may help to explain why degree completion rates of remediated students lagged behind degree completion rates of their cohorts. In fact, the NELS:88 report, combined with its follow-up data in 2000 (NELS:88/2000) found that only 28% of beginning two-year remediated students earn any degree or certificate within 8.5 years compared to the 43% of their nonremediated cohorts who did the same (Attewell et al, 2006).

Four-Year Colleges

Data from students entering four-year public colleges showed that 31% of students at non-selective colleges took at least one remediated course, and that only 52% of remedial students completed bachelor’s degrees compared to 78% of non-remediated

students who did the same (Attewell, et al, 2006). Because Attewell's study used data from the NELS:88/2000 survey, which only followed students for 8.5 years after high school graduation, actual degree completion rates for all students may actually have been higher because about 25% of bachelor's degree recipients take longer than 8.5 years to complete their degree (Attewell, et al, 2006).

Remediation and Persistence, in Summary

Placing into a remediated math class in college correlates with a reduced likelihood of earning a degree. In Attewell's (2006) study, only 52% of entering four-year college students and only 28% of entering two-year or community college students completed any degree or certificate within 8.5 years.

Transferring and Persistence

Some of the reasons students attend two-year or community colleges include upgrading their skills for a particular job, completing a certificated program, earning an Associates degree, and completing the requirements for transferring to a four-year college.

Persistence from First to Second Year

Persistence rates for first-to-second year community college students is included in the Integrated Postsecondary Education Data System (IPEDS) data set, collected each year by the Department of Education from over 7500 institutions. The IPEDS data showed that in 2008 approximately 59% of full-time two-year college students persisted from first to second year (Digest of Education Statistics, 2014). However the National Student Clearinghouse, which collects nationwide data from 3600 colleges and 96% of U.S. college enrollments, followed almost 1 million entering two-year college students

from 2008-2014 and showed that the rate of credential attainment (i.e., associates and bachelor's degrees and certificates) from a two- or four-year college was 39.1% within 6 years of first entering a community college (Shapiro & Dundar, 2014, Figure 12). Thus persistence from year one to year two does not necessarily translate to degree attainment.

Transferring and Bachelor's Degree Attainment

About 81% of students who entered community college intended to complete at least a bachelor's degree at a four-year institution, but only 21.1% were shown to have transferred within 5 years of first enrollment, according to BPS:2004-09 figures (Horn & Skomsvold, 2011, Tables 1-B and 3-A). Furthermore, National Clearinghouse data, which examined students who transferred to a four-year institution during the academic year 2005-06, showed that of those who transferred, about 62% earned a bachelor's degree within 6 years (Shapiro & Dundar, 2013). Their research also showed that bachelor's degree attainment rates were higher for those who transferred with an associate's degree (72%) than for those who transferred meeting only the transfer requirements (56%). In all, roughly 16% of all students who began at a community college and transferred to a four-year college ended up earning a bachelor's degree within 6 years (Shapiro & Dundar, 2013).

Transferring and Persistence, in Summary

Of the 81% of students first attending a community college who intended to transfer to a four-year college, only 21% did so (Horn & Skomsvold, 2011). A separate study showed that only about 16% of entering community college students actually graduated with a bachelor's degree within 6 years (Shapiro & Dundar, 2013).

STEM Majors and Persistence

Using data from the BPS:04/09 study, Chen (2013) found that 28% of 2003-04 college entrants had majored in a STEM field at some point in the 6 years following entrance. However, this study also showed that 56% of beginning college students who declared STEM majors left those fields within 10 years, a finding supported by NPSAS:04 data which reported that the actual number of declared STEM majors in 2003-04 was only 14% of the undergraduate population (Chen, 2009).

While the attrition rates for STEM majors in general and mathematics in particular are large, the data reveals that there were influxes of other majors into STEM and mathematics at the same time students were departing STEM majors. For instance, using BPS:04/09 data, Chen & Ho (2012, Table 3) showed that between 2003 and 2009, 10.9% of all social/behavioral sciences majors transferred into a STEM field, as did 8.2% of humanities students, 14.1% of business majors, 10.5% of education majors, and 27.5% of health sciences majors

Hereafter, as defined by Chen (2013), students who achieved a STEM degree within 6 years of entrance, or who were still enrolled in college as a STEM major 6 years after entrance, are called STEM persisters. Those students who had not earned a STEM degree within 6 years, or had earned a STEM degree but had earned a subsequent non-STEM degree at the end of 6 years, or were not enrolled in any STEM major 6 years after entrance, are referred to as STEM-leavers.

Community Colleges, Two-Year Public Colleges

For the academic year 2003-04, 19.9% of all college students who started in a two-year college declared a major in a STEM field, with 0.7% specifically declaring

mathematics (Chen & Ho, 2012, Table 1). By 2009, only 30.7% of entering two-year students who intended to earn a bachelor's degree in a STEM field had earned a STEM degree or were STEM persisters, while approximately 20%² of students who declared as a math major in a two-year program had done the same (Chen & Ho, 2012, Table 2). Table 2 also shows that the percentage of beginning two-year math students who did not persist in math programs through 2009 was 37.6% for four-year declared math majors.

Various characteristics of STEM majors were tracked in the same report, including highest mathematics in high school. Of the 69.3% of entering two-year STEM majors who did not persist, 32.8% switched to a non-STEM major, and 36.5% left post-secondary education without a degree. Of the STEM majors who switched majors, 38.9% completed Algebra/Trig; 32.6% Pre-Calculus; and 37.1%² Calculus as their highest level of math in high school. Of those who left college without earning a degree, 31% completed Algebra/Trig, 27.3% completed Pre-Calculus, and 26.7% completed Calculus as their highest math class in high school (Chen & Ho, 2012, Table 4).

Four-Year Colleges

In 2003-04, 27.8% of entering four-year students declared majors in STEM fields with 1.7% of beginning students majoring in mathematics. By 2009, only 51.7% of entering STEM students were STEM-persisters, while 62.4% of mathematics majors persisted in a mathematics major or had completed a math degree (Chen & Ho, 2012, Table 2).

² Estimate is unstable because the standard error represents more than 30% of the estimate.

The same report detailed highest math taken in high school showed similar trends for four-year STEM entrants. Of the 48.3% who did not persist, 28.1% switched to a non-STEM major, and 20.2% did not earn a degree. Of those who switched majors, 32.5% completed Algebra/Trig; 32.1% Pre-Calculus; and 23.7% Calculus as their highest level of math in high school. Of the STEM majors who left college without completing a degree, 26.7% of those students completed Algebra/Trig, 19.6 completed Pre-Calculus, and 12% completed Calculus as their highest math class in high school (Chen & Ho, 2012, Table 4).

STEM Majors and Persistence, in Summary

The study by Chen & Ho (2012) found that only about 30% of entering two-year STEM majors and about 50% of entering four-year STEM majors achieved a STEM degree or persisted in their studies at year 6. They also showed that high school attainment of at most Algebra or Trigonometry was a characteristic of the largest group of STEM leavers.

The Demand for STEM Majors

Using figures from the Bureau of Labor and Statistics (BLS), the U.S. Department of Commerce (DOC) estimated that in 2010 the number of STEM workers was 7.6 million people (Langdon, et al, 2011). In the same report, the DOC stated that between 2000 and 2010 the number of STEM jobs increased 7.9%, three times faster than non-STEM jobs during the same period; in fact, STEM jobs were projected to grow 17%, compared to just 9.8% for non-STEM occupations, between 2008 and 2018.

While more than two-thirds of STEM workers have a STEM degree, “almost two-thirds of the 9.3 million workers with STEM undergraduate degrees work in a non-STEM

job” (Langdon, et al, 2011, p. 4). Besides the loss of STEM degree-holders to other fields of work, foreign nationals who graduate with a STEM degree from a college in the United States, and who return to their home countries after graduation, deplete the number of STEM graduates available to fill jobs. According to U.S. Immigration and Customs Enforcement, in 2014 there were approximately 344,000 non-immigrant foreign students studying STEM disciplines in the United States under F-1 and M-1 Visas (U.S. Immigration and Customs Enforcement, 2014). These Visas are only used for studying in the United States, so STEM graduates studying under them cannot be counted on to join the workforce. All of this means that colleges need to produce more STEM graduates than there are available STEM jobs as not every STEM graduate is willing or able to work in a STEM position.

The need to produce STEM graduates has been identified as a national priority by the Department of Education (Chen, 2013), and the failure to meet students’ needs for STEM education will have “serious implications” (National Science Board, 2007, p. v) for the country’s science and engineering communities. Indeed, it has been argued that, “addressing this issue is absolutely essential for the continued economic success of the Nation and its national security” (National Science Board, 2007, p. v). Many things can be done to encourage more students to pursue STEM degrees, e.g. summer STEM learning programs for high school students (PCAST, 2012), and this will eventually result in more STEM graduates. However, “retaining more students in STEM majors is the lowest-cost, fastest policy option” (PCAST, 2012, p. 1) to fill open STEM jobs and the other non-STEM jobs that benefit from the skills that STEM graduates possess.

Concluding Remarks

Taken together, the above-referenced studies suggest that students who begin in remediation and successfully complete advanced STEM degrees may be rare. The purpose of this study is to explore commonalities among the lived experiences of remediated students who successfully complete a mathematics degree, despite these seemingly insurmountable odds.

CHAPTER 3

METHODS

Introduction

The purpose of this study is to explore the reasons for remediated students' persistence to, and successful completion of, a mathematics degree, despite the seemingly insurmountable odds these students face. In particular, this study aims to understand commonalities among these students' lived experiences. Since this is a question of "how" rather than "how many," a qualitative, rather than quantitative, approach was warranted.

Qualitative research is conducted when problems need to be studied for which a rich and detailed understanding of the issue is lacking. In fact, Peshkin (1993) writes that one of the beauties of using a qualitative method is that the outcomes are not determined by preconceptions of the researcher, but can result in "many imagined and as yet unimagined outcomes" (p. 23). Since this study seeks to explain a phenomena that does not lend itself to simple explanations, methods that open the door to unimagined outcomes were necessary.

While there are a variety of qualitative methods from which to choose, phenomenology was the best fit for this study. Phenomenological studies seek not only to describe the meaning for several individuals of their lived experiences but to also distill those experiences down to derive the common reasons for which the phenomena exist (Creswell, 2007). Phenomenology is consistent with studies examining student success from their own perspective (Berry, 2008; Martin et al, 2014).

Experimental Design

Population

The population for this study was current graduate math students or recently graduated (≤ 5 years) students from the graduate math program at a state university in California. All 58 graduate students in the mathematics and statistics department, as well as 69 alumni, were invited by email to participate in the study (see Appendix A for the email solicitation). The graduate students were invited through the math list serve, after the department chair after approved the content of the email. The alumni list was generated by the Alumni Affairs office and contained the names of alumni who had earned their graduate degrees within the last five years, and for whom the university had current email addresses. Delivery of four of the emails permanently failed for three alumni and one graduate student, thus the final number of people who received an invitation to participate was 123, composed of 57 current graduate students and 66 alumni.

Participants

Participants were selected based on two criteria: 1) a placement in remediated math upon entering college, and 2) being in the process of completing, or having already completed, a graduate degree in mathematics. There were ten respondents, eight of whom met the requirements to participate. All eight qualified respondents, comprised of five graduate students and three alumni, participated in this study. Two female Caucasians, one female of Middle-Eastern descent, one female Hispanic and one male Hispanic comprised the graduate students; of the alumni, two were male Hispanics and one was a female Caucasian.

Data Collection Procedures

For this study, I conducted semi-structured audiotaped interviews. Semi-structured interviews were appropriate because each participant had a unique story to tell. By using open-ended questions, I was able to guide the conversation to relevant topics, such as math biography and support systems, while also allowing the participant the latitude to deviate from the expected responses, to freely express his/her ideas and opinions, and to include information that he/she believed to be important. In this manner, additional topics were raised, such as participants' employment during college, which were then included in subsequent interviews.

Before the interview was conducted, each participant was handed a consent form (Appendix B) to read and sign indicating his/her willingness to participate in the study. The participants were told that the purpose of conducting taped interviews was to allow the participants to tell their own stories, in their own words, without the distraction of notes being taken as they spoke. Questions and prompts (Appendix C) were introduced to ensure that a participant's math biography, college history, historical attitudes towards math, and perceptions about his/her reasons for success were included. Without the constraints of note-taking, the conversation was kept relaxed. The interviews lasted from 30 to 70 minutes, with participants occasionally being prompted to fill in the details of their stories in order to give a complete history of their journey to degree. For instance, during his interview Frank mentioned the use of study groups when discussing his tutoring position at the community college where he first attended. I later followed up by asking "study groups... you mentioned them earlier... do you think they were an important part of your persistence and success?"

Once each interview was finished, a debriefing statement (Appendix D) was given to the participants to read and take with them. A follow-up phone interview was later conducted with select participants to complete gaps in information given in their initial interviews and/or to clarify information given in their initial interviews. The interviews were later transcribed.

Data Analysis

Analysis of data was done in a series of phases. The initial phase was transcribing the interviews, and familiarizing myself with the stories. During this phase, pseudonyms were assigned to each participant as well as every person and institution mentioned by the participant during the interview.

The second phase involved note-taking and identifying commonalities in the topics addressed by each participant, as well as an initial attempt at generating categories. Initial analysis of the data resulted in 41 codes. Comparing the codes and collapsing related codes into single categories resulted in a total of 11 categories.

The final phase of analysis was to review the transcripts to make sure that all data was retrieved and codified, and to revise and refine the categories in order to describe all data. At this point, codes with less than 6 participant entries were excluded. For instance, one category that was generated during the initial phase of analysis was Support Programs. This category included any on-campus support programs that helped students to be successful financially, academically, etc. while in school, and included services provided by EOP (Educational Opportunity Program), Veteran's Affairs, and various other college programs. The types of support recorded here included tutoring programs, priority registration, and stipends. The category was removed during the final analysis

because only four of the respondents indicated that they received such services and/or identified those services as important to their persistence to degree.

Researcher's Identity

I am a graduate student in a mathematics program at a California University, and a graduate teaching associate in the preparatory math program therein. I began my current college journey by earning an Associate of Science in Business degree, at a community college. As I prepared to transfer to the university, I was surprised to discover a rekindling of my interest in mathematics, and after a placement test put me into a Trigonometry class, I stayed at the community college to finish out my calculus sequence. I then transferred to the University where I earned my bachelor's degree, and now, with this thesis, my master's degree as well.

While my own math history is in many ways reflected in the stories of the research participants, I sought to be impartial and unbiased, using peer-reviewed articles and other readings to broaden my perspective about remediation prior to interviewing the participants of this study. While conducting those interviews, I relied on my background as a math student to draw out the stories of the participants and utilized that knowledge to recognize and code the resulting data.

CHAPTER 4

RESULTS

Aristotle (384-322 BC) wrote that “the whole is greater than the sum of its parts” (Metaphysics, 1045a.11). This is true of the participants in this study; they are more than a collection of results supported by a few quotes. Two of their interview stories are given here, revealing the diverse characteristics of the participants in this study, which in turn support the results that follow. Please note that because individual colleges and universities have different titles and numbering systems for their remediated math classes, for the purpose of clarity in this study remediated classes were named as follows: Math 1 refers to Pre-Algebra, Math 2 refers to Beginning Algebra (high school Algebra I), and Math 3 refers to Intermediate Algebra (high school Algebra II). All other classes that are mentioned have been renamed according to the topic of the class in order to protect the identity of the institutions. Please note that the initials KA in the interview excerpts refer to the interviewer, Karen Amagrande.

Frank’s Story

Frank holds a master’s degree in mathematics from Cal U, something he never considered possible growing up. He thought he might be able to earn a bachelor’s degree in some subject, but a master’s degree was never a consideration. Furthermore, a degree in math, any degree in math, was unlikely; he states that being a math professor “was never, ever, in my wildest dreams one of my options.”

Frank grew up not liking math even though he believes that he didn’t struggle with the subject. He was asked if he thought he was good at math during high school.

Frank: No. I just thought it was some ... I never struggled with it, I thought it was some innate ability that I had that, 'hey, I'm not struggling with it as much as everybody else is, but I don't like it.'

During that time, however, Frank did have a memorable Algebra instructor who was able to engage Frank with the material.

Frank: I had a Algebra teacher ... one of the summers, I had to take a remedial math course to graduate, and it was an Algebra I course during the summer. And I had this very ecstatic math teacher. And he came in and he always drew me in with his attitude of positive, high-energy "this is what we're going to do" exciting, uh, "we're going to have fun today", and that's what drew me in.

Then Frank took Geometry, and it caused Frank to hate math more than ever. Frank described how he struggled with the subject matter as well as why he didn't seek assistance.

Frank: Geometry, yes, I struggled with, and that's what held me back a lot, too, was looking at Geometry and ... more the logic, because in high school I had no outlet for to seek help. Um, you know, and especially going to school in [the city where he grew up], um, you know, you're seeking help, and that's ... to me that was a sign of weakness, so I never sought any help. And to me, struggling with it just meant it's not for me. So that's what Geometry taught me in high school.

KA: Wow, so there was like no support system for you to get...

Frank: Right.

KA: OK. And, obviously, the teacher wasn't a good source of support for you?

Frank: No, this uh, this teacher in Geometry, he would get there, he would turn off the lights and he would lecture using the overhead projector. So, if people were sleeping, he didn't care. Uh, and he didn't really care if you learned the material or not.

Frank felt he struggled not only with the subject matter but also because of the lack of assistance and the instructor's apparent lack of interest in the class and students.

After completing high school, Frank did not go straight into college, and he stated that maturity played a big part in that decision. He believes that if he had attended college immediately after high school he "wouldn't have been in the right frame of mind to complete any of the courses I would have enrolled in." So he enlisted in the military and after training stateside went overseas. It took four years for him to decide that the military was not a good fit for him. Frank then came back to California and enrolled in a local community college as a sign language major. The required math placement test placed him in the class that preceded Math 1, four classes below College Algebra.

Frank credits being in the military with being prepared for college. Regarding his time in the service he stated,

Frank: Taking that break, and having the military structure, having that discipline to stick to something and ... having so many life lessons taught in the real world... actually gave me the discipline to sit in the class and put forth a real effort.

Along with developing the discipline needed, he credited the military with teaching him to complete what he started, to put forth his best effort, to pay attention, and to do the work.

Frank's first attempt at math at the community college level was successful despite the fact that his attitude toward math was poor. He believes the placement test was correct in putting him in a class where basic operations were being reviewed, and his confidence with math improved when he found he didn't struggle with the material.

Frank: I took that [Pre-Math 1 class], and I didn't struggle with it, at all.

Everybody in there, they were ... I, the placement test was right. I needed

to be in there to brush up. Uh, I didn't struggle at all, as compared to the rest of the class. I think I was, uh ... I did extremely well in that class. And I approached the teacher at the end of the semester, and I asked him "would it be possible for me to take the placement test again, and place into a higher level course because I don't want to take Pre-Algebra? I think I'm slightly better than that. I remember most of this from high school." And he said "no, my recommendation is for you to take Pre-Algebra." However, this person that ... this instructor... was not a math professor. He was the football coach.

Frank admitted that he doesn't like to be told no. So upon discovering that the instructor did not hold a degree in math but was a sports coach at the college, Frank realized he was asking the wrong person for permission to advance himself in his math education.

Frank: So, uh, looking back at it, I asked the wrong person, cause he wasn't really evaluating my skills at that time. So, what I ended up doing was I ended up grabbing a lot of study sheets from the admissions office at [the community college], and I ended up studying those. And I thought I was well-prepared to take the placement test again, so I went, and I skipped Pre-Algebra, and I placed high enough by placing into Intermediate Algebra, which is the equivalent of Math 2 here. So I was able to place into that class, and I was super excited. I had studied and I did something out of my own accord, and I was able to skip a class. So I ended up going into Beginning Algebra. And so I skipped Pre-Algebra.

Frank's success at reviewing the math on his own and skipping a prerequisite course fostered confidence in his math skills and encouraged ownership of his education.

Furthermore, Frank learned how to navigate the educational system to achieve a desired outcome despite the hurdles placed in his way. During that first semester at community college, Frank was also required to take an intro to college course during which guest

speakers came to broaden students' perspectives about job opportunities. This exposure to different career paths was one reason for his eventual decision to study math.

Frank: I've always been interested in Sign Language, so I figure I'd try something in that aspect. So, that was my first semester. I also took an Introduction to Life Journey, or something, like that? I can't remember, it was one of the required courses. Um, and in that class we had a guest speaker, he was a radiologist, and he said, "oh, if you don't struggle that much with math, if you're really good at spatial reasoning, you know, this might be interest... this might interest you. We make this x amount a year". And as soon as he told me that, I'm like, I fit all those requirements, I'm going to be an x-ray tech. [laughs] So my major for the longest time at Mountain View was an x-ray tech.

KA: And is that the reason you continued with your math classes?

Frank: Yes. Um, that is... that ... in order to get into the program, you have to meet prereqs, which was you had pass beginning algebra. Which I had just placed into. So that, said ok, I gotta pass this class. I gotta get a C. Um, I took the class and I took the professor, and it was the most horrible thing I could have done. That class discouraged me for a whole year.

KA: Because of the professor?

Frank: Because of the professor.

Frank's experience in his Beginning Algebra class left him feeling inadequate, and although he was one of only ten students out of about thirty to pass the class, he believed that the professor felt he wasn't ready to move on in his math studies.

The wait list to get into the radiology program, once Frank met the prerequisites, was two years. Frank decided not to waste those years, and he opted to get his associates degree while he was waiting. Since an associate's degree required Math 3, Frank registered for the class. To ensure his success, he took a leave of absence from the

logistics job he held; he had recently become a father and the Family Leave Medical Act allowed him to do so without fear of losing his job. This time the math came easy.

Frank: The professor I had was soooo great. She explained everything really well. Oh, she made sense of everything. And, I didn't struggle. And everything just came naturally. I, I, I... that's when I figured out "this isn't so tough". I don't know what the big fuss about it was. And so I was the highest person scoring in the class. And, you know, everyone was always quiet, because everyone always assumed it was the little Asian girl who sat in the corner, and she was quiet. [laughs] Which she was second. But she wasn't first.[laughs] So I secretly knew what I got, you know, and that's when I knew, I was sort of good at this. Because previously I had never really struggled with it, but nobody ever really helped me develop what I had.

KA: Right.

Frank: And it wasn't until this class that I figured out, "Hey, everybody in this class was struggling. Why not me? What was so different?"

So Frank ended up with a professor who, from his perspective, was amazing at explaining math - a professor he felt made sense of everything - and his confidence in his math abilities returned. Frank also noticed at this point that he was not struggling at all with the material although everyone else in the class appeared to be struggling. So after discussing everything with his wife, Frank decided to pursue a bachelor's degree, rather than an associate's degree, in radiology. This required him to take Pre-Calculus.

To speed up the education process he opted to enroll simultaneously in College Algebra and Trigonometry the following semester against the advice of his advisor.

Frank: So right after the summer, I said "I did really well in Algebra II so, you know, I'm going to take both of these classes together." So I enrolled, and I told my counselor the same thing, and I told her "you know what, I did really well. I think I'm ready for Al ... College Algebra and

Trigonometry, at the same time”. They advised against it because they said no student should take two science courses together in one semester.

KA: OK.

Frank: Plus at that time I was frustrated because everybody had been telling me at this point “you should not do it, you should not do it”, you know, so I was frustrated. And I was like, “no, I need to do this, like I’m getting older, I’m not as young as these other people.” So, I enrolled in them. And I did extremely well. Um, I got an A in College Algebra, I got a B in Trig, only because I didn’t perform well on the third exam.

Frank again took control of his educational journey by choosing to go against his counselor’s advice. While he received an A in Algebra, he earned a B in Trigonometry due to a personal emergency which caused him to leave the final exam 30 minutes into the final with the final only half completed.

Frank: Uh, the rest of the exam I was just “I can’t do the rest”. Um, but again, the professor did not approach me to say “hey, what happened? Previously you had scored a 90 and above on both of the exams. What happened on your third exam?”

KA: Yeah.

Frank: You know, there was nothing, there was no approach. So, again, I went under the radar.

As Frank points out, the teacher never asked why he was leaving, and never contacted him afterwards. This experience made Frank feel as though he was unimportant and invisible to the instructor despite Frank’s achievement in the class.

It is interesting here to note that during his community college education, Frank did not attend office hours, and this may account for his professor’s inaction.

KA: So you didn't have any kind of rapport with your teacher? I mean, were you going to his office hours or anything at that point?

Frank: I didn't know what the full purpose of office hours was. I think if somebody would have taken the time at the very beginning of college and told me 'hey, this is what office hours are for', I think I would have utilized that a whole lot more."

While he did not make use of office hours, it was at this time that he discovered the Math Tutoring Center. There Frank met a student-tutor, Matt, who had also started in Math 1 and who impressed Frank with the breadth of his math knowledge.

Frank: Matt, Matthew Gabriel, um, to me as soon as I saw that guy in, uh, when I was taking Trig at Mountain View, and I was like "how does one person know all this? You know, I think he was taking Calculus or Calc II at the time. I was like "how do you know all of Trig so well? Like you're just a student. You know, I was like, you could be a professor already!" [laughs] Um, that amazed me, and from then on, you know, I looked up to him. So, he was one person that I definitely looked up to, and I was like "if this guy can do it, why not me? Why can't I do, why can't I perform at that same level?"

Frank, who described himself as competitive, was motivated by Matt's background and achievements to not only persist, but to excel in his studies, i.e. to do as well as Matt.

While Frank was enrolled in Calculus I, he followed Matt's lead and obtained a tutoring position at Mountain View. He tutored in both math labs on campus, assisting students in all levels of math from remediation through Calculus. He credits his tutoring experience specifically with reinforcing the subject matter of the lower level classes:

KA: So do you think that tutoring was at all helpful in keeping you either motivated or in refreshing your basic skills, or ... what do you think?

Frank: Refreshing all the math that you've learned. I didn't know how much tutoring was going to help me until I actually started tutoring. Um, and I

started tutoring and it made me realize ... tutoring made me realize some of the problems that I was having, other people were having, and it made me correct those problems. So freshman FOIL? No more. Um... that all started coming into fruition once I started tutoring. And I started saying ok, that I got down, I started clean... I started cleaning up my math skills, uh, while I was tutoring, and it really helped me out for my later math classes, because I didn't struggle with those problems. A lot of people ... like in my study groups, a lot of people would be struggling with this, this and this, and it was like no, I just tutored it, I know this, I ... I... I ... this is my skill, I brushed up on it. So, um, you know, tutoring definitely, definitely, helped.

Frank's math skills were not only reinforced, but his confidence in the material and in his interactions with his peers was also improved through tutoring.

Frank's goal, while he was enrolled in the community college, was to study in the radiology program. However he hadn't been accepted into the radiology program by the time he was finished with his other classes at the community college so he made the decision to transfer to the university. During this time, Frank was enrolled in a Calculus I class, and after talking with his College Algebra/Calc I professor he decided to pursue a math degree. He applied to Cal U as a math major with the goal of earning a teaching credential and becoming a high school teacher.

Frank: I had been accepted with the requirement that I finish Calculus I at Mountain View because I was enrolled in Calculus I. So, finishing Calculus I, that's when I realized "I'm really good at Math. You know, I was working 40+ hours, I was only doing maybe two hours of homework for calculus in a 6-week course, and I was still beating almost everyone in the class.

However, just after being accepted to Cal U as a math major, Frank was notified that he was also accepted into the radiology program at the community college, which posed a dilemma: stay at the community college or head to the university? He decided to transfer to the university and completed his Calculus sequence and basic Statistics course before transferring to Cal U.

Frank: They called me to tell me I was accepted into the program a week after I had been accepted into Cal U. So it was either start Cal U or go into the radiology program which I had waited two years to get into. At that point in time I told myself if ... I'm going to go to Cal U because it's a bigger deal. I worked very hard to do this. So I said I'm going to go to Cal U. If I, at any point if I get an F, I will drop out, and I will go into the radiology program within that one year period because I had a a... I had a one-year extension for the radiology program, for me to get accepted. So I said if within that year I get an F in any class, I'll go straight into the radiology program.

KA: Mmm-hmm. And I assume you didn't do that since you're still here.
[laughs]

Frank: No. The first quarter. I got an F. And I met this wonderful person in this class. Uh, not...indirect. I met this person indirectly. So I met Judy and this wonderful person, through the extension of Judy, said "you shouldn't give up."

KA: Who was that?

Frank: Susan. Uh huh. And I met Susan and she said, "Look. It's one bad teacher. You need to be here."

KA: Mm-hmm.

Frank: And I needed to hear those words at that time. And that's when I said "OK, I'll try it again." So, if it wasn't for her, I would've left Cal U. So everybody plays an important role in your life.

So Frank opted to pursue a math degree and subsequently failed his first math class during his first term at the university; he stayed in the program because a cohort persuaded him to stay. Failing that class undermined Frank's confidence and caused him to be insecure with his math abilities for the next two terms.

According to Frank, he stayed at Cal U because he believed he needed encouragement to persist; recognition and words of encouragement were something he felt had eluded him in earlier classes like Geometry and Trig.

Frank: Once I got here, to Cal U, it was definitely more faculty members that took, uh, that took more of the time and saying "hey, you know, you're ... you're doing good." [laughs] You know, it's like "you've got a knack for this, so, you know, don't let anybody tell you different." And it was ... that's the things that you need to hear.

KA: Yeah.

Frank: And I didn't hear that until I got to Cal U. Until I got higher than, um, proof-writing. That's when I started hearing that and I was like, ok, that's what actually helped repair my confidence that was broken from that first proof-writing class. You know, hearing Dr. Rowe say "no, you're good, like your scores are really good, like you got a knack for this, like don't let anybody tell you different" you know. Hearing Maggie say "you belong here", you know, um, hearing Carly say "hey, you're doing really well", you know, to me that really, really helped. It really helped boost my self-esteem, and I think in math you need to not break students down. Cause math itself is hard. The math will break students down themselves. As a teacher you need to keep reminding them that they're doing all that they can, and that it's ok. And so I do that with my students, and I tell them "hey, you know, you're doing all you can, and that's fine". You know, you're doing great. If they do good, I say "great, you know, you're awesome", you know. If they start talking negatively about themselves, I

stop that, because you don't want to add to it, and you don't want to see them keep adding to it.

Frank's perception of being overlooked in math classes in high school and community college gave him a thirst for acknowledgement, which he felt he received at the university. As an instructor he uses that awareness in an endeavor to help his students feel positive about their own math abilities so they stay motivated.

The experience of failing a class during his first term at Cal U led Frank to reevaluate his school strategies; he changed his work routine, took advantage of his veteran's status, and changed his study habits to facilitate success in his classes. His 40-hour workweeks at the logistics company were interfering with his school commitments, so he quit his full-time job and opted for campus jobs in order to focus on school. His tutoring position at Mountain View ended after he was at Cal U, so he sought out tutoring and grading opportunities on campus to supplement his family's income. His veteran's status meant he was eligible for priority registration and this allowed him to get the classes/instructors he needed to succeed. Additionally, he realized that simply studying on his own no longer worked for him. So for the first time, Frank joined study groups.

KA: With study groups you mentioned them earlier... do you think they were an important part of your persistence and success?

Frank: Yes. Um, again, study groups I didn't start until like I got here to Cal U, and I think they were an instrumental part to help me get my degree. Uh, the whole unique perspectives that different people brought just amazed me. The different struggles that everybody brought to the table. You know, and I think we were very efficient within our groups to try to help out everybody as much as we could. Um, I think so long as everybody pulled their weight. [laughs]

Frank later stated that, “I learned in those study groups that other people knew different material that I didn’t. And I knew other material that people didn’t.” He felt that was important to succeeding in his classes. Additionally, Frank believed that competition within the study group was a motivating factor in keeping him working, and the group of people with whom he studied kept him focused. As he states about his choices in friends and study partners, “I’m very susceptible to peer pressure.[laughs] That’s why I choose the people that I hang out with wisely, because I’m very susceptible to peer pressure.” Frank believes friends and cohorts were an important reason for his success and persistence.

While study groups were important to Frank’s success, he discovered that his private study habits evolved over the years, going from no studying at all to picking up habits from study partners and cohorts in shared classes, as well as in response to professors who suggested that he try different techniques.

Frank: I say they evolved because when I started off in college, I needed to change my study habits from not having any to having some. And then from having no study habits to really formulating how am I going to do this homework in this amount of time, and really focusing on that. And my study habits basically evolved from that, analyzing every single time. What do I need to do in order to perform at the level that I need to be at. Um, you know, they said, “hey, you gotta know these theorems” I’d say, “ok, I gotta know these theorems. I gotta write them down on a notecard, and I gotta study them.” Um, as soon as I figured out hey, you don’t need to memorize theorems so much as how to apply them...

KA: Big picture?

Frank: Right, as a big picture, then my study habits needed to change. So I saw it as they constantly kept evolving until the very end whereas OK, I ... my study habits can’t evolve anymore. I... I made them into what they

worked for me. And, as study habits are indivi... are ... they vary from person to person, my study habits don't work for anybody else. At least I don't think they do. [laughs]

He said that his change in study habits was a response to changing work schedules, limitations on his time, and a need to perform at a higher level despite those restrictions. His initial goal in studying was to get good grades though he later realized that learning the material was more important than the grades:

Frank: I think I was for awhile I was focused on ... I think most of my undergrad was focused on grades. Uh, as soon as I figured out what my study techniques are, that worked for me. I think I was focused more on grades than learning. And it wasn't til grad school that I realized "oh, crap, I kind of need to learn this, and then the grades will come." So, for my undergrad it was grade, grade, grade, grade, and then grad school it was, like, "yeah the grades are very, very, very important, however, you need to learn this."

So studying for Frank involved private work and group work and he credits both with helping him to complete his degree.

Support systems were important to Frank's persistence to degree, and he received support from most family and friends. Frank is the first in his family to earn a bachelor's or master's degree, and while his parents did not live locally, they provided moral support. Each decision to further his studies placed financial stress on his family but his wife was supportive through the process. Friends, especially friends in the graduate program, were understanding and offered moral support. However, his extended family could not understand why he would spend so much time working at something for which he was not being paid, and they questioned why he was chose to study rather than to

attend family functions. Frank says, “for a long time my family didn’t understand what I was trying to do. It was kind of like foreign to them.”

Frank did not plan on attempting a master’s degree in math, but things fell into place because Frank’s friends lured him into the program.

Frank: So, um, it wasn’t until about my senior year that... or actually maybe a little bit before my senior year, maybe it was around the ending of my junior year here at Cal U, that I... that I started realizing I did not want to teach high school, and maybe college might be more of my calling, and then after that was when everything starting falling into place. Was when my friends said, “hey, I’m getting my master’s, I’m not going to finish here”, I said, “ok, well, maybe I’ll follow suit.” And then they said, “Hey, we’re taking these graduate courses”, and I said, “ok, I’ll take those graduate courses, too.” And so, yeah, so towards my senior year, that’s when I knew I wanted to go into college, I didn’t want to go into high school, and towards the end of my ... at the end of my senior year, that’s when it all came into fruition.

Frank was persuaded to take a graduate Real Analysis course that opened up at the beginning of his final year of undergraduate studies; this was followed by the second course of graduate Real Analysis and two graduate Complex Analysis courses. Before he walked in his undergraduate graduation ceremony he had completed half of the requirements for his master’s degree. He looks back at the accomplishment and credits it to his choice of friends.

The road to earning his degree was not always an easy one and Frank identified his biggest hurdles to finishing his degree as financial issues and lack of academic support. He was self-supporting all the way through college, working jobs in logistics, the military reserves, tutoring, grading and teaching. The military did provide a stipend for a

year after he arrived at the university, but when that ran out he took on those different jobs to help support his family. As far as academic support, Frank stated that “you take any class, proof-writing or below, and anybody in the math tutoring center can help you. You take anything higher and you start running into issues...you don’t get the proper tutoring, the proper tutors to help you out.” So he felt the academic support declined as you got farther along in the major; he overcame this hurdle by utilizing study groups.

As for Frank’s biggest academic accomplishments, those were easily identified: his master’s degree and his induction into a national math honor society. His master’s degree was important because “a bachelor’s, I might have thought about it in high school, maybe even before, but a master’s ... that was never in my plan.” Later he added,

Frank: Inducted into the math honors society...

KA: The math honors society?

Frank: Yeah. I thought that was really neat. Especially because I always struggled with math, and it was like wow, I made it into like the honor society, that’s really amazing! [laughs]

KA: That’s, that’s great! Honestly.

Frank: Yeah, so I ... I think that one and my master’s are just like, two that I never, ever, saw happening.

In hindsight, Frank’s view of how he persisted to degree is an interesting one and may be related to his goal-setting style. He believes that setting short-term goals was helpful to his persistence, but he acknowledges that he has trouble setting long-term goals and so those were not a factor.

KA: Do you think that you’re like a totally goal-oriented person and just having a goal was helpful to you, or...

Frank: Yeah, having a goal definitely is helpful to me, though I have trouble setting long-term goals because I’m like, “how am I gonna know where

I'm gonna be in ten years? Like, ten years ago I didn't know I was gonna be sitting here!" [laughs] So I have trouble setting long-term goals, I like to set short-term goals. Um, and I think that helps out a lot.

Frank's initial goal was not to get an undergraduate math degree, but he did; he never intended to get a master's degree in mathematics, but he did. He believes that he was swept along by his success in various math classes, and unexpected opportunities opened up in terms of classes, cohorts, professors, and jobs that just "threw him down a path."

In retrospect, Frank's persistence to degree had to do with many things: support of faculty and family; wisely choosing friends and study partners in the program; financial support in the form of education stipends from the military; lessons learned and maturity formed during his years in the military; a review of math due to his placement in remedial classes; being competitive; learning how to navigate the educational system to achieve a desired outcome despite the hurdles; being swept along in math as he chased bigger degree objectives which required additional math classes; a growing confidence in his abilities due in part to his tutoring jobs; a short-term goal setting style that complemented being swept along in math until he realized that it was his calling.

Grace's Story

Grace is a current graduate student at Cal U who is pursuing a master's degree in applied mathematics. Grace was born in a Middle Eastern country, and spent her early years attending school there until her family immigrated to the United States when she was in the third grade. By that time Grace was far ahead of her peers in terms of math, but her lack of mastery of the English language prevented her from moving ahead in math.

Grace: “I was doing long division, factoring, multiplication, like you name it, I was doing it. When I came to American, cause my English was poor, I was in the third grade. And I was always behind on the English, but when it came to the math it was, like my teacher, my third grade teacher, was just shocked. So I had to be at the same level as everybody was, I couldn’t be in any GATE class cause of my English. So then [...] in seventh grade, I was like in the regular seventh grade math, and my teacher comes up to me and she’s like “I really wanna put you in Geometry for eighth grade, but the school won’t let me cause your English is still not, you know, it’s not good [...]. And I was like, “OK, that’s fine.” So that ended up causing me to be [...] my senior year I took Pre-Calc, that’s the last one I took. And throughout all my math, I was always dominating, I owned those classes.”

Grace believes that she ended up repeating math content, not because she was incapable of doing the math, but rather because her English skills were poor.

After high school, Grace was accepted into Cal U as a biology major with a goal of going to medical school. She took the placement exam and was placed in Math 3, and she enrolled in that class during her first term at the university.

Grace: “When I took the test, I didn’t think it was... I didn’t take it serious, whatsoever, and that’s a big mistake on my part. And I ended up being in Math 3. I was like effing two points away from being in regular math. So, my fall quarter I was in Math 3, and I forgot my teacher, but she was a grad student, she was a GTA as well, and she once came up to me and said “why are you in my class?” And I said this was, like this was my situation, and she was like [...] “you’re literally getting 99’s on my midterm”, she was like “this ... this is ... you know like it’s not fair for ...” and I felt bad, you know?”

Grace stated during her interview that she believes that if she had studied before the placement exam, or had taken it seriously, she would have scored higher and avoided

taking Math 3. However she recognizes that there were advantages to starting at the remedial level in college, and one outcome was that she changed her major.

KA: It seems like it's a story of taking things over and over and over again. And then you come here and you have to take all these classes, starting at Math 3. What advantage was there for you starting in Math 3?

Grace: I got to review all my Algebra again. I... I... Algebra is like one of my strongest subj ... not Abstract, like Algebra it's one of my strongest subjects because factoring, I can now see things, and I'm just like "oh you gotta do... oh this is how you factor it." So it was like, it was good that I ...I actually am glad that I started out in Math 3, because it gave me that whole year, well, like, two quarters, to figure out what I wanted to do with my life. And my math was still fresh. Had I not started out in Math 3, I probably would have gone on a hiatus for math. Probably not... like probably majored in like history or biology, where I only had to take Stats 1, so I'm kind of glad that me taking that math class helped me cause it also helped me with my decision. I can't live without math.

Taking Math 3 reinforced her Algebra skills and reminded her how important math was to her. She enrolled in a basic statistics course the following quarter where she says that she "owned that class," and realized that she wanted to major in math. As she said in the interview, "I didn't feel like I was a student if I did not have a math class." So she changed her major to pure math before the end of the second quarter of her first year at Cal U.

Grace indicated in her interview that a number of faculty members were instrumental in advising her and providing support during her undergraduate and graduate journey, and credits her persistence, in part, to those professors. Dr. Adams was not her assigned advisor, but she provided advice on how to skip Pre-Calculus and head straight into Calculus the following fall. Grace credits Dr. Adams timely advising with

getting her into the calculus sequence and upper division classes more rapidly than she would have otherwise, allowing her access to a variety of classes and instructors that otherwise would not have been available.

Additionally, Grace credits her Calculus I professor with helping her to realize that she wanted to be an applied mathematician. The female lecturer had also attended Cal U, and held an applied mathematics degree, and Grace recounted that

Grace: I was like “oh yeah, I’m applied math.” Cause [...] first I wanted to teach, so she’s like “you know you can teach with applied math”, and I was like “OK.” So then I switched to applied math.

This same lecturer was in charge of the math tutoring center on campus, and she recognized Grace’s math skills, encouraging her to apply to be a tutor.

Grace: She literally was like “apply.” So I applied. I was like “are you going to set up an interview?” She’s like “no, you’re hired.” [...] Like, “you’re hired.” And I started that following fall, and it was just ... it was just amazing. Cause she was, she ... Wendy’s another person that no matter what, you can always go to her for advice, you can be like ... I come by “did you have to struggle when you were a graduate?” She was like “yes”. So she can, like, relate ... cause she was... she did it, you know, she was there. She did it. Yeah. [...] I love... I love that job. It’s fun.

So in Wendy, Grace found a caring instructor, a boss, and a mentor. This helped Grace to persist.

Grace credits Dr. Maggie Fleur with providing mentoring in the form of long-term advising and emotional support during all her years at Cal U:

Grace: “Sometimes she’d be like, “wait another year for this professor.” But then she would also be like... because she knows my situation, so she’ll be like, “don’t take it with this professor”, you know, or “you doing [...] like three of these classes, that’s not good for you.” But then, she doesn’t only

like help me with my school, but any time I'm feeling down I can just like stop by her office, and just having her... just sit there and listen, and give me back her feedback, or me, I can be, like, texting her like, help me."

This is the same professor who told Grace, when she was struggling with Abstract Algebra and did poorly on a midterm, that "this stuff, like you're never gonna see this stuff [...] that's why you're applied." By saying this, Maggie provided the support Grace needed which in turn prevented Grace from leaving the program.

One of Grace's biggest struggles has been that she suffers from severe test anxiety, and she found that the personal and caring nature of the professors in the department helped her to persist despite the anxiety. For instance, her Calculus 1 instructor took her aside to talk about the disconnect between her knowledge of the material and her test scores:

Grace: I struggle with really bad test anxiety. So, even Wendy Barrett, my Calculus I teacher, I would go to her office, I would know what I was doing and ask questions in class and answer questions and she graded my test in front of me and she was like "I don't get it, you know this stuff."

Grace felt as though Wendy knew her well enough to recognize the disparity in her knowledge of the material and her performance on tests. That, along with the later offer of a tutoring position, gave Grace confidence to continue.

In an effort to help Grace with her anxiety, the instructors in the department began to work with her, and she appreciated their help:

Grace: I was taking ... Real Analysis with Dr. Rowe. Maggie told Dr. Rowe, she was like "Grace gets panic attacks. So if she needs to walk during a test, if she needs to leave, let her." Dr. Rowe was like "Grace, Maggie told me if you need anything, just go. Just do what you need to do." He's like, "I know you don't cheat."

Grace persisted because she perceived her professors knew her, that they had confidence in her and trusted her, and they exhibited flexibility in their instructional methods to accommodate her needs. Grace also stated that a professor once said to her “you know, one test does not define you,” so she always thinks of that. “One test does not define me.” And that, too, has helped her to persist.

Grace believes that the support of friends is vital to her success. She related that her undergraduate study group moved on after graduation, and she needed to find a new group:

KA: So do you have like a cohort, or a group of people you study with? And does that help?

Grace: Yeah. It does help. Actually, even as a undergrad I think having that, like, stable group. Cause my undergrad team, they all ... one went to do the MBA, one went ... got a job... so my two girlfriends, like my two like rocks, went MIA. [...]

KA: They left you?

Grace: They left me! [laughs] So when I did the master’s program I found ... so it was in graduate Real Analysis classes, if you don’t have a study group you can’t survive. No. No way. Like no way.

Additionally, at one point Grace felt that she was not good enough to be in the graduate math program and was considering leaving the program to pursue more meaningful work. Her friend, Jim, prevented her from leaving. Grace said “Jim was like ‘you cannot quit.’ He was like ‘over my dead body, you’re not quitting.’” And so she persisted in her studies.

Grace also identified the support of her parents as one reason for persisting in the program. She cites that both her mother’s side of the family and her father’s side of the

family are rife with STEM majors, and her parents were happy when she decided to pursue a math degree. She stated that:

Grace: My parents were 100% supportive and they, because they know my conditions and stuff so anytime they see me that I'm struggling, my mom will be like "Oh, come, let's go, let's go have coffee", or my dad's like "oh let's go for a walk." But they're very supportive, even like when I wanted to quit the master's program, my dad would be like "Grace, you're almost there, like you're literally almost there." They're very, very supportive. They'll, my mom, she does not sleep until we all get home. And like, she goes "even if you need to come home at 2 am, cause you're studying", she was like "I'm awake." But, my family, they're very, very supportive. To put it... yeah they'll call me before a test, and like "it's ok, it's only a test, it's only a test, like relax, it's only a test."

Being able to rely on her family for emotional and financial support allowed Grace to continue in her studies.

Grace's math journey was not one where she was guided into the study of math by a series of events and opportunities, but was rather the result of a focused effort on her part to study something that she always loved. Her persistence to degree happened despite the sometimes-overwhelming challenges presented by language difficulties and anxiety disorders. The idea of dropping out of math has occurred to her multiple times but has been a temporary idea thwarted by professors who remind her that "one test doesn't define you," friends who refused to let her leave, and family that offers unconditional support. She decided on a math degree very early in her math journey, before she took College Algebra, and she persisted in reaching that goal. She completed her undergraduate degree in math and is now well on her way to a graduate degree as well.

Findings

Two of the participant stories were presented in order to demonstrate the complex nature of persistence of the participants in this study. The stories of Frank and Grace illustrate the complex internal and external interactions that culminated in a remediated math student persisting to a math degree. The interviews that were conducted revealed commonalities in character traits and experiences among the eight participants, some of which may help educators to identify and retain remediated students as STEM majors, in general, and math majors, in particular.

The eight participants in this study were randomly assigned a participant letter, along with a corresponding name. The participants labels A, B, C, D, E, F, G and H correspond to the assigned names Anna, Bruce, Cathy, Diana, Erin, Frank, Grace, and Hugh, and these labels will be used interchangeably for the remainder of this section.

Analysis of the 8 interviews resulted in four findings that appeared common to the majority of participants and their persistence to degree. These findings were designated as either *internal attributes* or *external factors*.

Internal Attributes

An internal attribute is a characteristic of an individual that enables him or her to persist; e.g. confidence, self-determination, etc.

Degree by determination versus swept along to a degree. Analysis of the data partitioned the participants into two groups: those who declared as a math major before attempting College Algebra, and those who declared after successfully completing many classes beyond Algebra, usually Calculus I or higher. The point at which participants

declared as a math major was used as a means to distinguish whether a student was “self-determined” or “swept along” unknowingly towards a math degree.

Three of the eight participants made a decision to study math very early in their math journey. Participants A, B and G each determined before completing College Algebra that they were going to complete a math degree, and their determination was unwavering. Participants A and G both began their college journey at Cal U, and they each attended the university directly out of high school. Both A and G took advanced courses in high school with A completing Math Analysis and G completing Pre-Calculus at their respective schools. While A and G always liked math they each chose to major in other subjects so upon arriving at Cal U they completed their required remediation classes and a class in basic statistics. However, each woman realized, before taking college Algebra, that a math degree was what she wanted to pursue. G recognized that she wanted to study math during her second term at the university, and she changed her major while taking basic Statistics, her first non-remediated class. In contrast, it took A a few years to realize that she wanted to become a math major:

KA: When you started off, did you come here as a math major?

Anna: No.

KA: What did you come here as?

Anna: Accounting.

KA: Oh really! And what made you change your mind?

Anna: I hated accounting. I thought it was math, but it wasn't, and I took one intro class, and I did ok. I think I got like a B or a B+, and I enrolled for the second class, core class, and I went the first day, and I was like, I can't do this. So then I just remember like, OK, what was it that I really enjoyed? Um, back when I was in high school, and I'm like, well I was really good at math and I enjoyed doing it. So I'm just going to become a

math major. And that's when I decided to switch, and I switched like my, I want to say either the end of my second year, so it was pretty late, or the beginning of my third. It was pretty late.

KA: Had you already taken a lot of other math classes before you actually switched?

Anna: I had only taken, well, Math 3 and Basic Stats, so I actually, I took the placement exam because it had been so long since I'd taken a math class. So I took the placement exam and it placed me in College Algebra. So then I took College Algebra and Trig together, and then just continued to take math classes.

After making a decision in the early stages of her math history to study math, Anna never wavered in her determination to earn an undergraduate math degree although graduate work made her question if she was good enough to be in the program:

KA: Did you every think about quitting it, at any point in the process, either undergrad or graduate school?

Anna: Undergrad? No. Grad, yes. My first quarter of grad school, oh my God, I was taking Topology, and Analysis. Yeah. I was taking those two and then Intro to Math Teaching, which is, ok, fine, but um, yeah. I would say there's a big leap from undergrad to grad school.

KA: Was it the amount of work, was it maybe your abilities you were questioning?

Anna: I would say my abilities. Yeah, my abilities I was questioning, like, I don't know.

KA: What made you persist? What I mean ... did you see anyone else struggling with it, what was it?

Anna: I definitely saw other people struggling with it so you do feel better when you're not alone. But having a strong support group, and also, I don't like being a quitter. Like I just hate the idea of not trying hard enough so I just felt like if I try hard enough, I can do it.

So Anna persisted not only to her undergraduate math degree, but into graduate school as well. Anna is one example of degree by determination.

Bruce also determined early that he wanted to earn a degree in math. He spent a number of years in the service, and after spending a traumatic day on the battlefield, he described sitting in shock outside his living quarters and thinking:

Bruce: I just don't want to do this for the rest of my life. [...] I don't want to do this. I want to help people for the rest of my life. Well, what can I help them with? Well, I don't know. What do I suck at? Math. Ok, that's it. We're going to teach math.

So Bruce returned from the service, enrolled in college, placed into Math 3, and determinedly started toward his degree. He never felt like he was good at math, but he persisted because his mind was made up.

Bruce: Umm... I've been terrible at math my whole life, and so I knew, before I started, I was probably going to have to put in twice as much time as everybody else in the same classes, and so I would regularly, like in algebra I studied my ass off, a lot, and I was genuinely surprised when I would get good grades, which is weird, it's like "oh, OK".

Despite the hurdles placed in his path, including administrators who tried to discourage him because of the amount of time it would take to degree, he doggedly continued.

KA: OK, so you decided that you're going to study math. You end up going to Mountain View, you have to start in Math 3, did you ever consider how many classes you were going to have to take in order to get that degree, or did that not even figure into your ...

Bruce: Oh, no, I saw the number of classes that I was going to have to take at Mountain View, and when I signed up they said ok, you need to declare a major. And I said, "Oh, it's math."
"You can't major in math."

“Why?”

“Math majors start in Calc I. You have a year and a half of math before you get there.”

And I said, “Well, I guess I’ll be here an extra year and a half.”

KA: So you just made up your mind you were going to do it.

Bruce: Oh, yeah. I was... before I even started college, I knew, eventually, I was going to teach math.

Bruce is an extreme example of what I term a degree by determination. He summed his determination up when he said:

Bruce: My goal, sometime overseas, for the rest of my life was to alleviate that sort of math anxiety that I felt I had grown up with. And to make that a little easier for someone else, and show them that, hey, it’s not that you suck at math, it’s that you just need to put in the same time as everybody else does, and if you work at something, even if it’s really difficult and shitty, you can still do it.

A, B and G are examples of participants who decide to pursue a math degree at an early stage of their math development, and they stick to the plan despite any difficulties they encounter.

The other five participants appeared to be swept along to a degree. Like Frank, they did not intend to major in math at an early stage, but opportunities, improved confidence with the material, supportive cohorts, supportive professors, and/or other circumstances all had a positive influence on them, and the students switched to a math degree. For instance, H liked his initial teacher in the Math 2 class in which he was placed at Lakeview Community College. H had taken two years off between high school and college in order to work, but ended up enrolling part time “just to try it out and see if

it works". He completed Math 2 and 3, and then he ended up taking another course with his initial instructor.

KA: And then you did basically the equivalent of Math 3 ... which would have rounded out your preparatory math. And you passed that the first time?

Hugh: Yes, I did.

KA: Oh. And then where did you go from there?

Hugh: I ended up taking college algebra.

KA: OK.

Hugh: And then the funny thing is I ended up taking the same instructor, so that really helped me out. I knew how he tested, and I felt motivated and encouraged to do well on the class, not for myself, but also for him.

KA: You felt a connection with him and you wanted him to feel good about you?

Hugh: Yeah, yeah.

So H continued on in math classes because he liked the instructor and thought he might be successful in those classes, not because he wanted to major in math. He stated that he didn't plan on getting a math degree; according to him it just happened:

KA: Wow. So you get out of high school, you work for two years, you decided to try the community college part-time for four years? And then you transferred, you didn't actually get a degree? You just did the transfer requirements?

Hugh: I ended up getting an associates in math.

KA: Oh it was in math?

Hugh: Yeah.

KA: Was it planned that way? Or is that just what you ended up having classes for?

Hugh: It was not. Yeah.

KA: So you kind of fell into it.

Hugh: I kind of followed my instructor til... til the end.

H's transfer was also not part of a bigger plan, nor was it done in pursuit of a goal.

KA: I guess... did you ever consider, at any point, how many math classes you would have to take to actually get your degree? Because you were... you were going part time, and I don't know if you ever stopped to consider "hey, you know, look where I started, wow if I decide I actually want to study this, that's like ...

Hugh: There was never planning.

KA: [laughs]

Hugh: Even when I transferred to Cal U, it was one of those things where I did last minute, and I said "uh, I'm just going to do it." There was never a set plan, I'm going to do this and it's going to be cool and I'm going to take these many courses, and it's kind of like ... just kind of bumped into everything.

KA: Uh-huh.

Hugh: So, yeah, like I said, even transferring here was uh...

KA: How did you decide on Cal U?

Hugh: Honestly, the other University applications were done and over with, so... and I was doing this last minute, and I had two friends who actually took the calculus sequence with me, and they were going to transfer here cause they wanted to be engineers, and I said "oh, just follow them."

KA: Mm-mm

Hugh: So I kind of just following people. Not until I got to graduate school where I just kind of did my thing.

Later H explained that he declared math when he transferred to Cal U, but there wasn't any thought or plan or career goal, he just "kind of did it."

Diana was also swept along to her degree. She related that she was placed in Math 2 at the first community college, and she didn't pass. She switched to a different community college where she again tested into Math 2, but this time she passed the class. She said, "Once I got to the college algebra, and that's what I needed, I was like 'well, let

me see what this trig class is all about’.” Successfully conquering algebra gave her the confidence she needed to challenge herself with another math class. Later, she related that becoming a math major was not what she had planned:

Diana: Yes, but I still even looking back, I still think it’s weird that I even took math classes to get to the point where I wanted to major in math. Like I, cause I remember someone was asking me like, how’d you get through? Well, I just kind of kept taking math for a little while, and at that point I’m thinking I’ll still major in philosophy, maybe history, and then eventually I get to some mind-blowing math and I’m like “oh no!” My goal totally changed once I got a glimpse of what math really is.

Diana was kept in the pipeline toward a math degree by her own curiosity as well as favorable outcomes in each successive class she attempted. She decided – in her last semester at community college, while she was enrolled in calculus – that she wanted to be a math major. So she transferred to Cal U as a math major and persisted to degree. The remaining participants had unique, but similar, stories whereby they were swept into a math degree by circumstances.

So early determination was an internal attribute that enabled three of the participants to persist to degree. The remaining participants meandered through math classes and fell into a pattern of success in those classes until through a combination of circumstances (faculty, major requirements, interesting material, accidental completion of a degree) a decision was made to study math. For these students, external factors played a large role in keeping them in the STEM pipeline and enabling them to persist to a math degree.

External Factors

An *external factor* or *attribute* is an external force, something outside the individual's control, that played a role in the student's persistence..

Type of college and accuracy of placement. The participants fell into two distinct groups with a number of common attributes with regards to the type of college at which they started, and their perception of the accuracy of their placement exam. Six participants, including Frank, comprised the first group whose members first attended a two-year college. Participants B, C, D, E, F, and H all stated that their placement test either accurately placed them in a remediated class, or it placed them too high. For instance, participant B stated that:

Bruce: I feel like I could have started lower, or I should have started lower. I was genuinely surprised when they put me in Math 2.

Participant H had similar feelings about his being placed into Math 2 as a result of his placement test:

KA: OK. Um... do you think that the results of that test placed you accurately? Do you think that the class you were placed in in community college was an accurate placement for your skill level?

Hugh: Yes. Yes.

KA: OK. Do you think that there was any drawbacks or benefits to being placed at that level?

Hugh: No, the only ... I guess anything negative actually drew... was drawn from high school, because I was placed in remedial math course without any even ... consideration of my skills. So right, automatically, it put me in basic english, and basic math.

KA: In high school?

Hugh: High school. Without testing whether I was capable or not. So that happened in high school. But in community college I feel that the skills

that I had were representative of the test they gave me. If not, I probably should have actually been scored lower. Maybe Math 1.

KA: Oh... you think that you might have been placed too high?

Hugh: Maybe, yeah.

So H agreed that he belonged in remediation, but he also believed that he might have been placed too high.

Of those six participants who started in community college, five stated that the last class they successfully completed in high school was Geometry or lower. However, participant D said she completed Pre-Calculus at her high school but qualified this accomplishment by saying that it was a small high school with “really low standards and really low performance,” and that she wasn’t a good student while she attended that school. So six of the eight students who first attended community college felt their placement was correct.

The second group of students consisted of participants A and G. As stated in the previous section, A and G entered Cal U straight from high school, and both A and G believed that their placement in remediated math was not correct. As G recounts:

Grace: When I took the test, I didn’t think it was... I didn’t take it serious, whatsoever, and that’s a big mistake on my part. And I ended up being in Math 3.

Participant A also believed that her placement test was not accurate. A took Math Analysis twice in high school, the second time at her own request because she didn’t believe that she received good instruction the first time through, even though she had passed the class with a good grade.

KA: Why did you get placed in Math 3, if you came out of a math analysis background? Was it a test, was it a score? How did they place you there?

Anna: I don't remember. I, did we, I would assume you take a placement test, right?

KA: I think they take one of two placement tests.

Anna: Yeah, I want to say I took one of those, and I just scored poorly.

KA: You just scored poorly. So do you think you were accurately placed in Math 3?

Anna: No. I don't think so.

Although Anna didn't believe that she was placed correctly, when she retook the placement exam a year later in order to enroll in math classes after she declared as a math major, she retested into College Algebra/Trigonometry. The initial placement test may actually have been accurate despite her misgivings about it.

In addition to being asked about their high school math attainment, and placement testing and accuracy, participants were asked about the benefits and drawbacks of remediation. Eight of eight participants remarked that the main benefit of remediation, regardless of the participant's belief about the accuracy of placement, was that the class was a refresher, and that their foundation in algebra was stronger after finishing remediation. Participant E stated that, "the foundation, which was shaky, got relain by taking those classes." Grace's story reflected her belief that she might have quit math and majored in something else if she hadn't taken remedial math, so the benefits of remediation were more far-reaching than most students realized.

Interestingly, there was no consensus on any drawbacks of remediation, with only three of eight participants noting that the length of time to complete the degree was an obstacle, an issue noted by Bettinger & Long (2005). This isn't surprising given that most participants did not decide to pursue a math degree until well after remediation, so the

number of remaining classes to degree was not as daunting. Other drawbacks which were noted by participants were: one participant didn't have a clear idea of what math was; there was a lack of advising on which classes to take in both the community college and at Cal U; and one student's confidence was undermined since she had taken – and successfully passed – more difficult classes in high school.

Jobs During College. Math-related jobs were performed by all participants at some point during their college journey to degree. A tutored at a local homework center for K-6 students and at a local high school as an undergraduate; B, F, and H tutored students at the community college they attended; C, D and H tutored privately while in community college, with D tutoring elementary-aged children; F & G tutored math students at Cal U; E worked as a supplemental instructor facilitating group study at the community college she attended. Additionally, A, B, C, D, F, and H were all graduate teaching associates at Cal U at some point during their graduate studies.

Many participants credited tutoring with keeping their lower-level skills fresh. In Frank's story, he credited tutoring with helping him to recognize weaknesses in his own math skills, which enabled him to correct them before he progressed through his upper division courses. He also recognized the value of tutoring when he stated, "I didn't know how much tutoring was going to help me until I actually started tutoring."

Hugh obtained a tutoring position at the community college he attended while he was still taking College Algebra, due to his initial math teacher's recommendation:

Hugh: Following that instructor through the courses, he actually recommended me to tutor, and because of that I started tutoring, and that's when I really started liking math. Because just helping people was probably the biggest key, even before math became a thing, even though I was a math tutor,

like helping people and seeing them like happy because they were able to solve a problem, it made me really happy, and that's when math then later ... well, ok, I'm helping people, and I'm helping them with math, and math's not too bad.

Furthermore, Hugh credited tutoring with pushing him to learn and to be fluent in the material so he could quickly switch gears as he moved from student to student, and from topic to topic:

KA: Um, what level of math were you taking when you first started working there?

Hugh: Um, I think I was taking College Algebra.

KA: OK

Hugh: So I was doing low-level tutoring.

KA: Mmm-hmm

Hugh: And I started progressing, and as I... for example, I... even though I took ... I was taking College Algebra, I would tutor kids with College Algebra ...

KA: Uh-huh.

Hugh: ... and it kept going that way. So like as I progressed with calculus and stuff, I ended up tutoring that, too.

KA: Mmm-hmm. And what did that do for your skill set?

Hugh: Oh, it definitely improved it. Just all the different questions that people would ask and me having to think about it... it being a job actually added like to the stress of knowing how to do things. So it stepped up my game, like I was ...

KA: You had to be responsible for the information you were giving out.

Hugh: Yeah

KA: So you had to learn it better.

Hugh: Absolutely, and not only that it gave me the ability to think faster about problems because there's maybe three students and you would go to one student and they would ask you a question on a particular type of math.

You would try to help them, then you would move on, you would get different math, and then math again.

KA: Stats, Calc, Algebra.

Hugh: Exactly.

KA: Right?

Hugh: And you had to just shift your mind.

KA: Yeah.

Hugh: Yeah. So that definitely helped out in that sense.

Hugh credits his early tutoring job with forcing him to learn the material in order to be an effective tutor; he also believes his tutoring experiences made his thought processes more fluid, improving his ability to quickly switch between math topics. Interestingly, Hugh never declared as a math major at community college, but was surprised to be awarded an Associate Degree in Mathematics when he graduated.

Math-related jobs were common to all participants as undergraduates although the type of job (tutor/math facilitator/volunteer) and the level of tutoring (K-6, high school, community college, university) varied. For two of the eight participants, the math-related job began during College Algebra; for four others it began during Calculus. Of the remaining two students, one began tutoring after completing her Algebra sequence, and the other did not give a timeframe for the private tutoring she did. It is noteworthy that 4 of the 5 participants who “fell into a math degree” held the math job before declaring as a math major.

Support Systems. Three different types of common support groups were identified by participants as important to their persistence: family, friends and cohorts, and faculty.

Family. All participants identified either family support or family pressure as a factor in their persistence. Family support was identified by participants as one or more of the following: financial support, including food and lodging; emotional support in the form of encouragement; and academic support in the form of assistance with navigating the educational system, providing a positive view of education, and providing positive role models of success within their families.

Seven of the participants identified their families as being “very supportive”, or “supportive”, and one participant stated that she felt no support from her family at all. Five of the participants felt they had familial support through their entire educational journey while two identified receiving support only later in their education with one of those stating that his family “got on his side” and became “super supportive” only after he obtained his first degree. The participant who had no support felt only pressure from her family, and three other participants stated that in addition to family support, family pressure was a factor in their persistence.

Grace indicated in her story that she felt unconditional support from her family in every way: financially, emotionally, and academically. Cathy also indicated that having stability in her family helped:

Cathy: I think living at home really helped me just because my family’s very stable so my family’s very supportive, so I know that helps a lot. It’s really hard to concentrate on school if your life is going crazy, so... I was very blessed to have a very... Well there were periods where things were not as stable, but for the most part living at home, my family’s very stable, encouraged me.

And along with the encouragement she received, she also discussed her family's views on education:

Cathy: And part of it is just the way I was raised. My parents taught me that school is not about the grades that you get. It's not about the degree you get at the end, it's about ... I mean, those are good things, but education is about being educated and learning stuff, so I was blessed in that I grew up with parents that weren't just obsessed on what does your report card say. They taught me to be investigative, and curious, and want to learn.

Cathy's parents set the stage for her to be successful in school, and their support financially, academically, and emotionally helped her to persist.

Anna related how supportive her family was before and during college. She said that her parents always expected her to get a higher education.

Anna: Yeah. Yeah, for them it was, I think, since I was young, ever since high school, I remember my dad was like you're going to college. It wasn't "do you want to go to college?," no, it was "you're going to college." OK, so then I always had it in my head that I was going to college, and then, it didn't matter what I wanted to major in, so for them just the fact that I was going to college, like, they were happy with that. And then, yeah, I don't know, they were just very supportive to whatever I want to do.

But along with that support, and sometimes in place of that support, she felt pressure to finish, to succeed. Anna stated that one factor in staying in the program was that she didn't want to disappoint her family, or herself. She is the first in her family to go to college.

KA: So you stayed then, because you don't like quitting,

Anna: Yeah. I would say that's the biggest thing because for me I don't want to be a failure, especially to, like, my family because, I don't know, you know like you have a lot of pressure, well, I guess when your family

thinks you can do all these awesome things and you're just like, "you don't even know how hard it is", and for them to not have done, for them to not know what it's like, it's really hard to come back and be like, "you know what, I couldn't do it." Like, you want to, you want to set that standard or, like, for your family.

And the pressure to do well in Erin's family came not from supportive parents who never attended college, but from family pressure to keep up:

Erin: Yeah, um, I... my family has... I mean my oldest brother, who we call the favorite, because ...

KA: ...he is...

Erin: ...my father has said out loud, or had said out loud that he was the favorite, [laughs] in like a weird way, but that's a whole different story, but, uh, yeah, so it's clear that, you know, James is the favorite and he is the one that got his Ph.D. and he works at [a research university], and everything is perfect for him because he led such a diligent lifestyle, you know, like, nose to the grindstone, you know, he was in the service, and all this stuff, and so everything was... just worked out great for him, but he's worked very hard to do so. So. And then the second brother... I have six... so I hope you have time for all this [laughs], the second brother, he did military school, and he's an engineer. And then, um, we're all mixed so I'll cut out everyone else, then there's me. So, and... um... I think I always fought with the two, the dueling worlds. I have a little bit of my mom in me, and that's very hard. Addictive personality, whimsical, what a devil-may-care you know, versus very, very strict and to the point. [...] "do what is expected of you and do it right" and all this stuff. So it's like [...] So, it's on my Dad's side expected like... well it's not expected, I think I think it's supposed to be expected. I think whatever I did it would have been fine. But it's like very engineer, Ph.D heavy on that side.

So rather than support, Erin felt pressure from her family to keep up and to finish her degree to fit in with her family.

The pressure felt by Frank came not from his parents but from having to support a family:

KA: So you talk a little bit about your, um, your family. I mean it sounds like your wife is very supportive of you. Was your family overall just very supportive of you?

Frank: Um... yes? [laughs] Yes. [laughs]

KA: That sounds very qualified. [laughs]

Frank: Um, well I mean [...] if one person is not bringing in a good, steady income, it gets a little hairy.

KA: Stressful?

Frank: Yes. A little stressful. Just to say the least. Um, so as soon as I got my bachelor's, theoretically I was supposed to go into my credential program, and get my credentials so I can start teaching right away. And, um, I decided to go into grad school. So postponing my income for another year was stressful to say the least.

KA: Mmm-hmm.

Frank: So, um, the support was still there, um, but it was nonetheless stressful. You know, with a family it was stressful, especially me spending most of my weekdays and weekends here, focused on passing my courses, excelling. Um, it was just... it was, it was tough. It was tough.

Frank stated that it was difficult supporting a family with the extended time to his master's degree. However family pressure was a driving force to apply himself diligently, and he completed his graduate degree within two years.

So family support and family pressure appeared to be driving forces in the participants' persistence to degree.

Friends and cohorts. Friends and cohorts were identified by all participants as important to their persistence to degree. The reasons that friends were considered valuable varied among participants, and they listed moral support, study groups, needing

to keep up with cohorts, and advice on which courses and professors to take as some of the ways they relied on friends to persist in their studies. Two participants mentioned that friends played a role in making decisions, good or bad, and so their choice of friends was important; in fact, Erin mentioned that “what influenced me to do poorly early on is like the wrong groups” so she believes that her choice of friends was critical to her success in school.

In Frank’s story, he revealed how he persisted at Cal U despite a failed class in his first term because of a cohort’s encouragement, and he also stated that he enrolled in graduate school because his friends lured him into it. He describes his friends, inside and outside the program, as supportive:

KA: Um, now, how about your friends? Were your friends supportive?

Frank: Yes. Um, I always had good friends, good supportive friends. Um, more supportive friends once I started making friends here at Cal U. I think friends that are in the similar situations as you are better equipped to help you out. Moral support-wise because that’s ... overall that’s what you need. You need that moral support.

Just as Frank credited friends with providing moral support, Anna stated that both her math friends and non-math friends provided the same, and their support inspired confidence in her own abilities and the desire to continue with her studies:

KA: Basically when you’re talking about a support group, what are you talking about?

Anna: Just math buddies.

KA: Math buddies?

Anna: Yeah.

KA: Ok. Homework groups, study groups?

Anna: Homework groups, study groups, yeah, just talking like, talking about it to other people. Math buddies, non-math buddies, I talk to my best friend all the time, and I'm like "I don't know if I can do this."

KA: So what did she say to you? What helped?

Anna: Ummm. Like for someone else to tell you like you can do it, you're smart, for someone else to believe in you, I think it pushes you and it makes you think like, "Ok, maybe I am, maybe I am."

So Anna got the support she needed to build her confidence and continue with her studies from friends both inside and outside school, and math buddies.

Math buddies, and study groups were an important and effective means of making it through grad school for other participants as well. Just as Grace explained in her story that surviving particular graduate class required a study group, and Frank explained that they were instrumental to his successful degree completion, seven of the eight participants stated that study groups were important to their persistence to degree. However, two of the seven stated that the primary reason they attended study groups was to be helpful to others: Cathy used study groups primarily for socialization but found them useful because "even if you're just helping to explain something you learn it better yourself," whereas Hugh stated that:

Hugh: Um... it was interesting. At first, I was a... a lone, a lone gun. I could do it... I felt I could do it myself. Um, and I would go to study groups just to help people out. But then grad school came along [laughs] and, yeah, we needed everybody's brainpower to get through things. So... yeah, at first... I started, I started in undergrad as a way to help, but then it became like really, really beneficial in grad school.

So study groups were essential to the success and persistence of most participants, and all participants benefitted from having a support system that included math and/or non-math friends.

Faculty. All eight participants credited faculty at Cal U with keeping them in the program and helping them to persist to degree.

In Grace's story, faculty were instrumental in providing academic and emotional support, and that helped her to persevere. Anna believed that she also had a great support system in the faculty, and that faculty provided both personal and academic support:

Anna: When I was in undergrad, I would always, like, stress about ok, these are the classes that I still need, which ones do I take this quarter. And for someone to just be like, this is what's available, take this and this, you can do this load, that helped out a lot.

KA: Anybody in particular that was helpful like that?

Anna: Maggie. She always set up, like, my schedule as an undergrad. Um, so I would definitely say that, or I remember one time when I took physics and I had never failed a test before, and I failed a physics test, and I was like, what? I just failed a test and so I doubted myself. So I went in there again and talked to her, and I'm like I failed, like, and she just, I don't know, just made me feel better, like, it's ok, you're going to do better next time.

And later Anna added "We have the best department, ever. [...] You even have a support system with faculty." So Anna persisted because a faculty member took an interest in her and provided personal support as well as individualized academic advisement.

Bruce echoed that sentiment when he discussed why he ended up transferring to Cal U, and why he subsequently stayed for grad school:

Bruce: I was not going to go to grad school here. I wasn't even going to transfer here. I was going to go to Berkeley. I got accepted to Berkeley, I got accepted to USC, and UCLA, and their math programs, but my mom

broke her back at the time I was getting ready to transfer, so I ended up coming here to stay local and to live with her and help her out, and that kind of thing. And I just, man, I had such a great experience with the math department. Lowry, as difficult as his classes were, is a sweetheart. Maggie is super approachable, super awesome. Rowe, man, my sister had a baby that was born three months premature, at the same time my mom was still racked up in the hospital with her broken back, and he was just really understanding in like, "I'm explaining this to you, and you get it, I know that the math is not a problem. It's the life that's getting in the way of the math."

KA: So, basically, he was encouraging. He was very understanding.

PB: Yeah. Oh, yeah, yeah. He's a big sweetheart. He's a big sweetheart. He's a professor, and he's a father, and he's just an all around sweet guy.

KA: Yeah. But he understands about life.

PB: Yeah. He's human. I really like this math department, cause when I imagine math people, they're mostly like Webster, where they're just kind of like robots, they just spit out facts, and start all their sentences with "well, actually". But Bob, Maggie, Carly, and he's not here anymore, but David Farr, Carly Jenkins, oh, man, I love these people. They're the reason that I stayed here for graduate school, instead of going somewhere else.

KA: Ok. That's good to know, because I know that you weren't going to give up on studying math, but the question was why did you stay here for that, and that's particularly because of the math faculty?

PB: Oh yeah, everything to do with the faculty. I just... I love the math department here.

So the reason Bruce stayed at Cal U was the faculty. Although he was a student who through self-determination was going to persist to his master's degree regardless of where he studied, he had a choice of which school to attend and he chose to stay because of the faculty support he received at the school.

Elizabeth explained that what inspired her was that the faculty acknowledged her input as valuable, and it motivated her to try harder.

KA: And what other support systems can you identify besides your friends and family?

Erin: Friends, family, faculty for sure. Like having faculty members that like don't like dismiss you. And just like here they're so welcoming. There's like rarely, I can't even think of someone right now that made me feel stupid, or something. You know what I mean?

KA: Yeah.

Erin: And that's like, just made me not like they would ever say that. Maybe in like stats or something, where like we just didn't click. And there's been teachers that I don't like 100% click with, but everybody, all the faculty here is so supportive.

KA: What kind of support do you get from them? I mean, are we talking letters of recommendation or just a pat on the back?

Erin: Yes, that, too, even just saying like "that's really interesting that you're thinking about that." Just acknowledging, like, my input as valuable, or my contributions as valuable. Like, rather than like "oh, I can't believe you're asking this, you should have known this a long time ago." Like, nothing like that, ever, really. I can't think of anyone right now, at least, that's done that. But more like, just like, "oh, I'm really happy you asked that question" or something. Just little stuff like that, it's like then it makes you like want to go back, especially for me, I want to impress everybody, even though, like, I don't think I'm that impressive, I just like am striving for other people's approval, especially like authority figures. And so, like, yeah, like "what question can I ask next week" and like motivates me to do better in classes.

So Erin's persistence was motivated by the recognition she received from faculty.

During the other interviews, the importance of faculty support was even more evident:

Diana: And then the professors here are um... well, I don't have any other universities to compare it to, but comparing it to community college, they're just so approachable and helpful and available, and I was blown away.

But faculty didn't just provide support, they provided challenge and opened the student's eyes to the wonder of math by sharing their passion for the subject:

Hugh: Confidence came when I took both sections of undergrad real analysis. Everybody told me like "if you can pass these classes, you're going to make it through, you're going to be fine." And I ended up acing them, so... and it was from Professor Granger, he was a notoriously difficult instructor. He would pick on me to answer questions, which most people would be horrified, but for whatever reason it made me excited, and I was always ready. So, yeah, I felt confidence then like "ok, I can make it through this." When I started understanding mathematics beyond just doing the problems, and like appreciating math, came when I took Abstract Algebra with Maggie. I learned what it means for math to be beautiful. Like I understood that and it was nice, and she was very... you could tell she was very connected with the math, like she would almost cry when she did a proof, like "this is so beautiful guys." And I'd be like, "you know what? I see it. Like that's nice."

So faculty supplied academic and emotional support to the participants, inspired confidence in the participants, provided challenge and rigor, and afforded participants with a glimpse into the beauty and structure of mathematics. In doing so, faculty helped the participants to persist to degree.

The participants, in general, found that the faculty were sensitive to their academic and non-academic needs, and indicated that they received the support they needed to continue in a challenging program. Additionally, the faculty were perceived to be flexible in response to student feedback, which kept at least one participant in the program at a critical point in his education:

KA: So, you get into the graduate program. Did you have any classes where you were like “I just can’t do this.”

Frank: Yes.

KA: Which one? Which ones?

Frank: The... only one. Topology. I... that one beat me down, it demoralized me, it turned me into a person that I never want to see again. It made me cry. Oh, my gosh, I think if there was a ... I think I was in very deep depression in that ... in that class. I did not like that course. And ... and I don’t know why, because it’s all real analysis, again. [laughs] I don’t know why, I just, oh my God, yeah. For, I think, for a good hour I quit grad school.

KA: [laughs]

Frank: I always say that ... for a good hour ... because I did not ... I did not complete the homework assignment that was due that day.

KA: Mmm-hmm.

Frank: And I realized, or I did the calculations that with my scores, if I had projected the same scores for the rest of the homework, I wouldn’t pass the class. And with me not completing that homework assignment, and it really made me not pass the class. So, I said to myself, “you know what?” ... or I said to myself and my friends, “you know what? I’m not doing the homework assignments. I didn’t do it. Uh, two hours is not enough time to complete it, so I’m just gonna not do it, and it is what it is. And I think grad school’s over for me.” That first quarter of grad school, and my grad school career was over. So for that whole hour, I was done.

So I just sat back and I reviewed my... I was reviewing my options as to what I was going to do now. I had my bachelor's, which was good enough. So, um, I was reviewing my options. While I was reviewing my options, we got an email saying "Apparently a lot of people are having problems with the homework. There's a homework extension for one week." [laughs]

KA: [laughs]

Frank: And I said "someone's looking out for me. Somebody doesn't want me to quit." So, I didn't quit grad school. [laughs]

KA: Because of that extension.

Frank: Because of that extension. Seeing that other people were struggling I was like "well, I now have a couple of more days to finish this." And I did. I cleaned up my act as much as I could, and I tried my best and I ended up passing the course.

Frank's instructor did not know that Frank was ready to quit grad school over a homework assignment, but he was responsive to student feedback on that assignment, and his willingness to grant a homework extension helped at least one student to persist to degree.

Faculty encouragement was instrumental in helping a number of students to not only enter the graduate program, but to continue education after attaining a master's degree:

Cathy: As far as the graduate... deciding to go into the PhD program, that was definitely mostly influenced by Dr. Earl, who was my thesis advisor. So he was the one who encouraged me that I should go on for a PhD.

KA: Mmm-hmm. If he would not have been there encouraging you, would you have moved on?

Cathy: Probably not.

KA: OK. Did he help you to research where to go?

Cathy: Mmm-hmm. No, he was like super-helpful through the entire process.

So, overall, faculty were an important part of student persistence to master's degree and beyond.

Perceptions about Achievement after Remediation

Two common perceptions - that remediated students do not achieve degree and that remediated students who achieve degree were incorrectly placed in remediation - were not supported by this study.

Remediated students do not achieve degree. The requirements for participating in this research were that participants must have started their math courses in a remediated math class in college, and that they must have been in the process of completing, or have recently completed, a master's degree in mathematics. Every participant in this study is a counterexample to the perception that remediated students do not achieve degree.

These participants were initially placed into the lowest levels of mathematics when they entered college. They not only achieved a degree despite their start in remediation, but they achieved a degree in mathematics. They stand as bright reminders to educators of the critical role that remediation plays in providing students with opportunities to succeed, not only in the remediated subject, but in college after remediation, and in the workforce after graduation.

Remediated students who achieve degree were not placed correctly in remediation. In this study, six of the eight participants believed that they were correctly placed in a remediated class, or they should have been placed lower. For five of those students, the accuracy of their placement is supported by the fact that the last class they

successfully passed in high school was Geometry or lower. Since Algebra 1 in high school is the equivalent of Math 2 in this study, a remediated math placement of at most Math 3 was warranted. Additionally, one student who successfully passed Math Analysis in her high school... twice... did not believe she was accurately placed into math remediation. However, when she changed her major to math she was required to retake the placement exam because too much time had elapsed since her successful completion of Math 3 and Stats. She tested into College Algebra, which supports that her initial placement was correct.

Other Results

There were many topics that arose during the interviews that were not found to be common to all participants and were thus eliminated during data analysis. Mentioned previously were academic support programs (i.e. EOP and Veteran's Affairs), which was mentioned by only four of the eight participants as being important to their persistence. Other topics that were not found to be common among participants included:

Family education level. The participants in this study came from a wide variety of parent education levels. For instance H's parents only had about six years of elementary education between them, while E's father double-majored in math and physics. D's father is a lawyer and her mother is a nurse, whereas B attended community college with his mom.

Sparks & Malkus (2013) provided a breakdown of the parent education levels of remediated students, showing that 19% of remediated students indicated that one or both parents had achieved at least a bachelor's degree. In this study, however, four of the eight

participants (50%) had at least one parent who held a bachelor's degree or higher when the participant started college.

Biggest hurdle. One might expect that students sharing a common remediated background in a common subject might experience common difficulties in achieving degree. Although all participants in this study identified roadblocks or hurdles to completing their degrees, no common hurdles – i.e. length of time to graduate due to remediation, lack of advising in the major, or difficulties in transferring and adapting to math classes at the university level – were identified by this group.

Biggest accomplishment. Similarly, one might expect that remediated students who persist to degree completion might share particular accomplishments related to their mathematical progress; however, this study did not support that expectation. Participants were asked about their biggest accomplishments while in college. Among the achievements listed were participating in an REU out of state; getting published; being invited to speak about her thesis at the research university she attends; putting herself through college and getting a really good GPA; graduating; getting his master's degree and getting inducted into a math honors society; and shaking the hand of the department chair when receiving his diploma. The variety of responses indicated that no common accomplishment or achievement was critical to the persistence of the interviewees, but it may perhaps indicate that feeling accomplished about some achievement was necessary to persist. While one might also expect that such accomplishments are important to every students' success, it is also reasonable to argue that remediated students are in particular need of feeling accomplished since they must persist in mathematics for a far longer period of time.

Summary

The interviews with the participants in this study revealed interesting facts and commonalities in their path to degree. First of all, some students decided early in their math journey, before College Algebra, to become a math major and they persisted to degree. This type of decision-making style is referred to in this paper as a degree by determination. The majority of participants in this study, however, fell into a math degree through circumstances and opportunities, and decided on a math degree much later in their math journey. They were kept in the STEM (or math) pipeline through external factors. External factors which were common among participants and contributed to their persistence included being placed into a remediated classroom where foundational math skills were reviewed; strong support systems in the forms of family, friends and faculty; and early math-related jobs where students repeatedly reviewed material from earlier courses which reinforced their math skills and enabled them to help others.

CHAPTER 5

CONCLUSION

What characteristics do math-remediated students who persist to a math degree have in common? There were four findings in this study.

First of all, math students fall into two types: those who decide to study math very early in their academic career and persist despite any hardships, and those who take math courses until they finally decide to major in it. Early determination earned three of the participants a degree; five of the participants meandered along a path with no plan to major in math until they realized they were far enough along, and they were good enough at it, that majoring in math became a possibility. Keeping students such as these in a math classroom long enough may ensure they stay in the mathematics pipeline.

Secondly, placement tests may not be perfect, but the data collected in this study suggests these tests appropriately placed the participants of this study. Even the participants who did not feel that they had been accurately placed stated that the review of algebra was beneficial to them in their progress toward a math degree.

Thirdly, support systems were very important to the participants in persisting to their degree. The role of family, friends, cohorts and faculty were often a determining factor in the persistence of these students. Specifically, faculty were instrumental in keeping students in the math program, whether by acknowledging students' contributions in class, writing letters of recommendation, providing academic counseling and advice, or providing a shoulder to cry on when things just weren't going well.

Finally, an early math job, e.g. tutoring or facilitation, provided the means for students to review earlier skills, become proficient in foundational math, and gain confidence with the material.

Limitations of this Study

A limitation of this study is that it was performed at one institution and had a small sample. The number of students in the graduate math program at this college who began in remediation was not known to the researcher and so the size of the student sample as compared to the total population of qualified participants was not known; neither was the number of recent graduates who qualified to participate versus the number who responded. Further, the reliability of the sample as a representation of the overall population of remediated math-degree-seeking students or math graduates could not be ascertained. This study was dependent on a response to the email solicitation, as well as a good-faith assumption that participants were being truthful as to their start in remediation.

While the sample may in fact be a good representation of the current and former math graduate students in the department at this college, it may not be representative of graduate math students or graduate math degree-holders everywhere, and so caution in generalizing these results is warranted. Conducting a statewide study in a large university system may overcome problems with the sample size, perhaps provide a better representation of the population being studied, and provide a clearer picture of what qualities a math-remediated student needs to persist to a math degree.

Further Study

This study found that early experiences in the form of mathematics related employment was a commonality among those who persist to degree completion. The link between early math jobs and success in persisting to a math degree has not been addressed by prior research and is a commonality that may be worthy of further study. In particular, researchers may wish to conduct quantitative studies to verify this commonality among larger cohorts. If a correlation exists, it may open up additional means by which to coax students into a math major who otherwise would not have been interested.

All participants in this study, regardless of their feelings about being placed into remediation, stated that reviewing foundational math skills was beneficial in their higher math studies. A survey of post-remediated, post-gatekeeper-class students measuring both satisfaction with initial placement into remediation as well as benefits obtained academically from that review (i.e. did the student experience any benefit in later classes as a result of the review of foundational math) might be helpful to educators in planning math requirements. Remediation studies, which measure academic attainment only (e.g., how successful was a student in passing all remediated classes or gatekeeper classes or did the student complete a degree), neglect students' perceptions of experience. The long-term effects of math remediation, including confidence and success in later classes and retention of students in math and other STEM fields, may outweigh the short-term drawbacks of longer time to degree.

Parent education levels of remediated students indicated that 19% of remediated students came from families in which one or both parents had earned at least a bachelor's

degree (Sparks and Malkus, 2013). In this study, 50% of participants indicated that their parents had earned at least a bachelor's degree by the time the participant began college. A study investigating the parent education levels of remediated degree-holders may help educators to better understand which remediated students are achieving degree, and may help to identify which students are in need of additional services and support to help them to persist to degree.

Concluding Remarks

It was an honor to interview so many bright, accomplished people in this study. I am grateful to them for sharing their experiences and perceptions, and for trusting me to share their stories. Their accomplishments are something to be applauded: earning any math degree is a noteworthy attainment, but earning a math degree despite being faced with multiple classes of remediation which may possibly add years of additional study, is something to be admired.

It is my hope that educators will walk away from this study with a greater understanding of the struggles faced by remediated students in pursuit of their degrees, that they will have a renewed respect for students who persist against such overwhelming odds, and that this research helps to counteract any negative attitudes or biases against remediated students that educators may have.

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APPENDIX A

EMAIL SOLICITATION SENT TO PROSPECTIVE PARTICIPANTS

Dear Cal U Graduate Math Students (or Graduates),

My name is Karen Amagrande, and I am a graduate math student at Cal Poly Pomona who is currently working on her thesis project. My research is focused on understanding students' persistence in mathematics. This study consists of a 60-90 minute interview with the possibility of a short (less than 15 minute) follow-up phone call. Interviews and follow-up calls are expected to be complete by the end of February 2015.

I am recruiting participants for this research who: (1) began college math in remedial math classes, and (2) are earning (or have completed within the last 5 years) a graduate math degree. If you meet the requirements of this study, and you are interested in participating, please contact me at klamagrande@csupomona.edu at your convenience to participate or to have your questions answered.

All interviews will be held on campus at a time convenient to you. There is no obligation to participate, even if you provide contact information.

There is no compensation for participating in this study.

Thank you for your time.

Sincerely,

Karen Amagrande
Graduate Math Student, Cal Poly Pomona

APPENDIX B

INFORMED CONSENT FORM

California State Polytechnic University, Pomona Informed Consent Form for Research Involving Human Subjects

You are being invited to participate in a research study, which the Cal Poly Pomona Institutional Review Board (IRB) has reviewed and approved for conduct by the investigators named here. This form is designed to provide you - as a human subject - with information about this study. The Investigator or his/her representative will describe this study to you and answer any of your questions. You are entitled to an Experimental Research Subject's Bill of Rights and a copy of this form. If you have any questions about your rights as a subject, complaints about the informed consent process of this research study, or experience an adverse event (something goes wrong), please contact the Compliance Office within Cal Poly Pomona's Office of Research at (909) 869-4215. More information is available at the IRB website, www.csupomona.edu/research/irb.

This document explains your rights as a research subject. If you have questions regarding your participation in this research study, please contact the investigators using the information below.

Remediation to Math Degree: Identifying Persistence Factors of Remediated Math Students Who Complete a Math Degree

Primary Investigator: Karen Amagrande

Contact: email: klamagrande@csupomona.edu

Phone: (909) 869-4989

California State Polytechnic University, Pomona

Faculty Advisor: Dr. Stacy Brown

IRB protocol # 14-0349

Voluntary Status: You have met the requirements for enrollment as a volunteer in a research study conducted by the researchers listed above. You are now being invited to participate in this study.

Before you can make your decision, you will need to know what the study is about, the possible risks and benefits of being in this study, and what you will have to do in this study. The research team will discuss with you the details, and they will provide you this consent form to read. If you decide to participate, you will be asked to sign this form. Your participation is voluntary; you may withdraw at any time without penalty and there will be no loss of any benefits to which you are entitled.

Purpose: This study is a research project being conducted to identify common traits of current and recently graduated (≤ 5 years) graduate math students who began their college math career placed in a remediated math class, and who persisted to a math degree. There is a shortage of STEM majors in U.S. colleges and universities, and this shortage may be lessened by identifying and recruiting students to STEM fields who may have been historically overlooked based on their entrance math placement.

Procedures: This research project consists of an initial face-to-face audiotaped interview, with the possibility of a short follow-up interview (≤ 15 minutes) via telephone at a later date. During the initial interview, you will be asked questions regarding your math history, reasons for choosing to study math, and factors which helped you to persist to a math degree. The interview will last between 60-90 minutes and will include questions regarding your math biography, historical attitude toward math, obstacles encountered in pursuit of a math degree, and reasons for persistence including self-efficacy, mentoring, and support systems. If subsequent interviews with other participants raise additional questions which were not addressed in your initial interview, a short telephone interview will be conducted at a time convenient to you

which will complete your participation in the study. All follow up interviews should be completed by February, 2015.

After the raw data have been collected, your name will be replaced by a pseudonym in any reports, presentations, or publications.

Commitment and Compensation: Your total participation in the study consists of one 60-90 minute interview and a follow-up phone call lasting up to 15 minutes. Both the initial interview and the follow-up phone call are voluntary. You will not receive financial compensation for participation in this study.

Possible Risks and Benefits: It is expected that participation in this study will provide you with no more than minimal risk or discomfort, which means that you should not experience any more difficulty than what would occur in your normal daily life. The foreseeable risks in this study include an accidental disclosure of your private information, or discomfort by answering questions that are embarrassing. If you feel uncomfortable or distressed at any point in the interview, please tell the researcher and she will ask you whether you wish to continue. You can refuse to answer any question, terminate the interview, or withdraw from the study at any time without penalty.

You will not receive any direct benefits from participating in this study. Your participation is intended to add to the knowledge about the phenomena of remediated math students persisting to a math degree. However, the knowledge gained from your participation may benefit other people with similar math histories.

Confidentiality and Consent: The investigator and staff involved with the study will not reveal any personal information which they collect about you. Any information that is obtained in connection with this study -- and which can be linked to you -- will remain private and will be disclosed only with your permission or as required by law. Your identity will be kept strictly confidential by removing your name and all identifiers. Once the project is completed, all interview materials will be destroyed. Do be aware that the results of this study may be published or presented at conferences. Your name, the names of your institutions, and any other identifying information will not appear in these presentations or publications.

Consent: I consent to participate in the study. I understand that my participation in this study is entirely voluntary and that I may refuse to participate or withdraw from the study at any time without penalty. I have received a copy of this consent form for my records, and I acknowledge that I am entitled to a copy of the signed form, upon request.

- I am over 18 years of age.
- I agree to participate in this research project by being interviewed on audiotape.
- I do NOT agree to participate in this research project by being interviewed on audiotape.
- I agree to participate in a follow up phone interview. To schedule the interview, please contact me by:
 - phone (____)_____ email _____
- I do NOT wish to participate in a follow-up interview.

_____ Signature of participant	_____ Printed name of participant	_____ Date
_____ Signature of primary investigator	_____ Printed name of primary investigator	_____ Date

APPENDIX C

INTERVIEW QUESTIONS AND PROMPTS

ENTERING COLLEGE

What **type of college** did you begin your higher education at? (2-year or 4-year)

Did you come **straight to college from high school** or was there a gap between the two?

If there was a gap, do you think the time off was beneficial to your success as a student? (maturity, responsibility, focus)

Did the delay have an impact on your decision to study math?

If so, how?

Entering college, **what major** did you declare?

If not math, **when** did you decide to study math?

Why? What prompted the decision?

Did you choose to study **pure or applied math**?

What was your **career objective** once you obtained your math degree?

MATH HISTORY

What was the **first** math class you took in college?

How were you **placed** into a remediated math class? (Testing/SAT/ACT/Scores)

Do you think you were **accurately placed**? Why or why not?

If not, did you find value in **repeating the curriculum** starting from algebra?

Can you give me your “**math history**”?

(highest math level taken in high school, starting classes in college, which classes you took at what institution?)

Did you ever consider **how many math classes** it would take for you to earn your degree
(starting from remediation)?

How did that impact your decision to pursue a math degree?

Did you **repeat** any math classes?

What was your attitude toward repeating a class?

Did others also repeat? How did that make you feel?

What **benefits** do you think you received because of your beginning placement
in remediation?

Were there any **drawbacks**?

What would you say are the **reasons you stayed in the math program**?

(note and explore each topic)

ATTITUDE

What was your **attitude toward math** upon entering college? (Love/like/dislike/hate)

Has it changed over time?

Did you think you were good at it? Why?

At what age/grade did you first believe you were good at math?

Did you ever think about **quitting math**? Why? Why did you stay?

Did you see **other people struggling** with their math classes? How did this affect you?

SUPPORT SYSTEMS

Was your **family** supportive of your decision to study math? Did you grow up in a math-
or science-centered home? Did your parents go to college?

Were your **friends** supportive? **Cohorts? Staff?**

Were **study groups** an important part of your persistence/success?

If so, when did you begin studying for math classes in a group setting?

What effect did **mentoring** have on your persistence in math?

What forms did the mentoring take?

(letters of recommendation/experiences of cohorts/tutoring/advice/
emails about opportunities)

MISC

Is your degree in **pure** or **applied**?

Tell me about your study habits over the course of your college career.

What **jobs** did you work during your college career?

Did you **tutor**? How much did tutoring others help you in your studies?

Did you **GTA** or teach? Was that helpful in completing your degree?

What was your **favorite math class**?

Biggest accomplishment? (internship/GTA/Honor & recognition)

What was your **biggest hurdle**? How did you overcome it?

LAST QUESTION

Are there any other factors that played a role **in your success in obtaining a math degree**?

APPENDIX D

DEBRIEFING STATEMENT

The interview you just completed is intended to help researchers understand the phenomenon of graduate math students who began their college math journey in remediated math classes. Understanding the factors that helped you to persist to degree may help educators pinpoint ways to bring historically overlooked students into math programs. This is important because the number of jobs for STEM majors (Science, Technology, Engineering and Math) is increasing but the number of American students pursuing those degrees may not be adequate to meet the demand.

Your participation in this study is very much appreciated. Thank you for helping to further our understanding of this phenomenon.

If you experience distress over any of your answers or wish to change any of your responses, please feel free to contact me by email at klamagrande@csupomona.edu or by cellphone at [REDACTED].

If you would like to talk to a counselor, you may contact Cal U's Student Health and Counseling Services at [REDACTED].