WINDING ROADS TO SUCCESS: AN EXAMINATION OF ELONGATED PATHWAYS TO DEGREE COMPLETION IN MATHEMATICS

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SIGNATURE PAGE

THESIS: AN EXAMINATION OF ELONGATED PATHWAYS TO DEGREE COMPLETION IN MATHEMATICS

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ABSTRACT

This study addresses the phenomenon of students taking longer than 6 years to complete a bachelor’s degree in mathematics. More specifically the goal was to identify and describe contributors to academic path elongation and the formation of mathematical identities over time. Both quantitative and qualitative research techniques were employed to achieve this goal. A large sample of students (mathematics majors), attending a college with emphasis in STEM disciplines, was surveyed in order to gain descriptive statistics. A small sample of those students was interviewed in order to provide case studies about students in elongated pathways to degree completion. Critical constructs used to analyze the data include notions of efficacy, identity, predisposition, and factors found to contribute to STEM choice.
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CHAPTER ONE
INTRODUCTION

The “Nontraditional” Student

According to the National Center for Education Statistics (NCES, 2014), a student is considered nontraditional if they exhibit one of the following traits.

- Delays enrollment into postsecondary education.
- Attends part time.
- Is financially independent of parents.
- Works full time while enrolled.
- Has dependents other than spouse.
- Is a single parent.
- Lacks a standard high school diploma.

Students are considered to be “minimally nontraditional” if they have one of these characteristics, “moderately nontraditional” if they have two or three, and “highly nontraditional” if they have four or more (Horn & Carroll 1996). In 1999-2000, 73% of undergraduate students had one or more of these characteristics (Horn & Carroll, 1996). This figure is expected to increase as the National Center for Educational Statistics (NCES) projects a 21% increase in students 25-34 years of age, and a 16% increase in students 35 years of age and above from 2009-2020 (Hussar & Bailey, 2011).

We undoubtedly exist in a time wherein the college population is ever growing and diversifying. Current populations now include the single mother, the war veteran, the first family member to attend college, as well as a multitude of other identities both traditional and not. As non-traditional student percentages rise, there is clearly a need to
better understand this population. Rather than broadly describe the non-traditional population, this study aims to focus on a very specific subset of them.

According to the NCES (2014) "59 percent of full-time, first-time students who began seeking a bachelor's degree at a 4-year institution in fall 2005 completed the degree at that institution within 6 years". This study is concerned with students who exceed the above length of time to degree completion, that is, who followed an elongated path to degree completion. More specifically, we will focus on students who exceed this length of time to obtain a degree in mathematics. From this point on we will refer to students in path lengths exceeding 6 years as following an elongated pathway to degree completion.

There are many reasons why students might follow an elongated path to mathematics. Perhaps full-time employment was accepted following high school. Perhaps students begin to build families. Perhaps students enter postsecondary institutions but lack guidance and mentors, who might otherwise expedite the process of choosing a major. It may be the case that none of these assumptions hold and the reasons are altogether different. Clear upon first inspection is one constant. The students of focus in this study have all experienced an academic path/trajectory toward mathematics lasting longer than 6 years. Though these students exceed 6 years to degree completion, their trajectories or path types may be different. We turn now to some basic distinctions among students’ path types.

Defining Path Types

There are specific path types, or trajectories, that are examined in this study. While each path type is elongated there is reason for the paths to be additionally categorized by the researcher with the following characteristics. An elongated path
toward degree completion may be *continuous* or *discontinuous*, and each path type may be further classified as *straight/linear* or *winding*.

A continuous path is one in which there is an ongoing progression of, and engagement in, one’s academic endeavors. In this case there are no periods of non-enrollment experienced by the student. Conversely, a discontinuous path is marked by starting and stopping enrollment one or more times over an academic career.

Discontinuities in academic path are common among students for a number of reasons. One might have lacked academic guidance or the financial support necessary to pursue higher education. One might also start a family at a younger age, or accept full-time employment offered after high school.

Both continuous and discontinuous path types will be defined as either straight/linear or winding. A continuous-straight/linear path will be categorized as one in which a student enters a postsecondary institution, does not experience periods of non-enrollment and knowingly participates in courses which will gain them a degree in mathematics. In this case the decision to pursue mathematics is made prior to or upon the students’ entry to a postsecondary institution. In the discontinuous case, the intent is the same however periods of non-enrollment are present.

A continuous-winding path will be defined as one in which students enter a postsecondary institution, do not experience breaks (discontinuities) in path, nor do they choose a degree in mathematics as the initial goal. Students in this path type may choose an alternative academic goal, and later find themselves wanting to pursue a degree in mathematics. The discontinuous-winding case does experience breaks but again a degree in mathematics was not the initial goal. A winding path, in this study, is marked by an
exploration of alternative majors or minors. Students on a winding path converge upon mathematics as a major of interest after such explorations and persist in the discipline towards degree completion.

**Elaborating the Issue**

There is a growing need for students to graduate and pursue careers in fields specific to the STEM disciplines (Science, Technology, Engineering, and Mathematics). Unfortunately this story often ends in attrition. “Among bachelor’s degree students entering the STEM fields between 2003 and 2009, nearly one-half (48 percent) had left these fields by spring 2009” (Chen, 2013, pg.14). Students who leave the STEM disciplines either switch majors (28 percent) or leave college without obtaining a degree (20 percent) (Chen, 2013). The attrition percentages are alarming given the projected need for STEM professionals. The U.S. Department of Commerce projected a 17 percent increase in STEM employment from 2008-2018, and policy makers have created and implemented a variety of programs which serve the sole purpose of encouraging/inviting students to participate in the STEM fields (Chen, 2013). There is certainly a need then to better understand how we might bring students to the STEM majors.

There has been much research regarding educational pipelines, most notably, the pipeline to college. “The pipeline is a concept used to define major junctures in the pathway to college enrollment. It begins with a student’s desire to continue her or his schooling beyond high school and ends with matriculation in a four-year college” (Horn, 1997, pg.6). In this study we will also consider what we might call the *college to mathematics pipeline*: the major junctures in the path to enrollment in a mathematics program. We explore the question, if mathematics was not the intended major upon
enrollment but was instead a major the student found themselves pursuing later, how do such choices occur when the prevailing story is one of attrition? How does one gain interest and persistence in mathematics over time, while many do not? That is precisely the focus of this study.

Indeed, in the STEM fields there is a need for enrollment, degree completion, and entrance into the workforce. As percentages for STEM related employment grow, so do rates of attrition. Students entering a post-secondary institution are more and more likely to be categorized as non-traditional (at least minimally) so how do we encourage these students to pursue mathematics? There is a need to better understand the non-traditional population of students which is in innumerably faceted. We focus then on a subset of these students. More specifically, we focus on those who exceed 6 years to degree completion in mathematics so as to provide a counter-story to the prevailing storyline of attrition in the STEM fields, to highlight characteristics and commonalities of these students through their stories so that the these characteristics may inform students, educators and policy-makers decisions as our educational system adapts to changes in the student population.

**Overview of the Thesis**

The next chapter, frameworks, provides a literature review for critical constructs used throughout the study. Following this chapter is the methodology behind the study. In this chapter there is a discussion of processes, participant selection criteria, measures, instruments, and the analytic methodology used following the collection of data. In
chapter four, quantitative (survey) results are provided, and in chapter five the qualitative results (case studies) are presented. The two results chapters are followed by a discussion of the results, implications, topics for further study, and closing remarks.
CHAPTER TWO
FRAMEWORKS

Mathematical Identity

Themes in this study will assemble to describe the formation of mathematical identities among participants. Pierson Bishop (2012) defines identity as a “dynamic view of self, negotiated in a specific social context and informed by past history, events, personal narratives, experiences, routines, and ways of participating” (p38). Thus, it may be that we build concepts of identity within ourselves while also being subject to social constructions. We might identify with that which is most acceptable given certain external constraints, or instead against those constraints. Each identity may be situational and change given certain conditions. Pierson Bishop addresses the “multiplicity” and “fluidity” of identity as it may be socially positioned or “actively invoked” (2012, p37-38). From this perspective identity is multi-faceted and often referred to as a continuum in which one exists more fluidly.

We can apply concepts of identity, using it as a lens, to study more specific situations. In this study, we explore the formation of the mathematical identities for students in elongated paths. Mathematical identity is defined by Martin (2000) as a mathematics-specific identity which is “composed of one’s beliefs about mathematics ability, the importance of mathematics, constraints and opportunities afforded in local contexts, and motivations to attain mathematical knowledge” (Martin, 2000 cited in Pierson Bishop 2012, p.40).

The above definitions, of both identity in general and mathematics-specific, will serve as a basis for what will herein be referred to as mathematical identity. We will, both
in the methods and results chapters, examine how students might situate themselves, within their own history and narratives, centered about their experience in and with mathematics. There are many attributes or strands which will be described as contributing to a mathematical identity.

**Self-efficacy**

Self-efficacy can be described as the belief in one’s ability to accomplish, or cope with, a given task. This study will employ theories of self-perception as outlined by Bandura (1982), who has done extensive work with self-efficacy, its function, and effects as an instrument with the ability to dictate human action. Self-efficacy not only plays a role in task choice, but also influences effort and the length of time that one might engage in a task. From a personal and cognitive place, “Self-referent thought mediates the relationship between knowledge and action” and self-perceptions of efficacy are acknowledged as contributors to both motivation and behavior (Bandura, 1982, p122). In this study, we will examine students’ self-efficacy in general and efficacy as it pertains to mathematics, as a component of one’s mathematical identity.

**Efficacy in Mathematics**

Efficacy in mathematics or *math-efficacy*, especially in precollege years, has been shown to significantly impact students’ persistence in the subject. Hackett and Betz have done extensive work in creating and implementing efficacy scales specific to mathematics. Hackett and Betz found that, “the concept and measures of mathematics self-efficacy expectations are proposed to have utility for the understanding and treatment of math-avoidant behaviors” (1982, p18). Lastly, in a longitudinal study, which followed roughly 6,000 high school sophomores through their first two years of college, it was
found that “the intent to pursue STEM…was significantly and positively influenced by math self-efficacy beliefs…which remained the same across gender, racial/ethnic, and SES groups” (Wang, 2012). In this study, measures (questions and prompts) which attend to issues of efficacy in mathematics are used to reveal more extensive information from the student-perspective. Such measures will be described in greater detail in chapter three.

**Productive Disposition in Mathematics**

A *productive disposition* in mathematics refers to a “tendency to see sense in mathematics, to perceive it as both useful and worthwhile, to believe that steady effort in learning mathematics pays off, and to see oneself as an effective learner and doer of mathematics” (National Research Council, 2001). Used as a strand of mathematical proficiency, productive dispositions are capable of development over time, and are fostered when frequent opportunities for sense-making are present, providing opportunities for students to “experience the rewards of sense-making” (National Research Council, 2001). In essence, if a student is able to experience rewards in learning and doing mathematics, they may be more inclined to further pursue it.

**Predicting Persistence**

Much of the focus in current research is placed on how we might predict persistence in students as they continue their education. Kuh, Kinzie, Buckley, Bridges, and Hayec (2007) identify significant contributors and predictors for academic success such as precollege experience and various levels of engagement which attribute to positive outcomes and productive practices. Precollege experiences, both positive and negative, have been shown to nontrivially influence how well a student performs
academically, and whether or not they will persist to attain educational objectives (Kuh, Kinzie, Buckley, Bridges, Hayec 2007, p43). Positive precollege experiences include mentor relationships, engaging coursework, and support in both the secondary school setting and in the home environment. Engagement, affectively or otherwise, in one’s academic experience also plays a large role in continued persistence. Students engaged in their academic experience are more likely to “engage in effective educational practices marked by increased faculty contact, participation in co-curricular activities, and having a heightened sense of belonging to the institution at which they attend” (Kuh, Kinzie, Buckley, Bridges, Hayec 2007, p54-59). Students in an elongated path would presumably need to maintain engagement over the extent of their academic career. In terms of engagement, it may be possible that students on winding or discontinuous paths experience a decrease which would cause a shift in focus. These shifts may be the impetus for exploring alternative interests or experiencing discontinuities.

There is also research which is specific to the discontinuities in students’ academic paths. Changes in expected pathways occur for many students in the transition to young adulthood (Messersmith, Schulenburg, 2008 p198). Students who plan to attend college may lose interest over time. In contrast, students who did not intend on continuing their education may find themselves with a regained appreciation for the learning process. Perhaps these students find themselves unexpectedly engaged, and begin to participate in academically productive practices.
Influences on Choice of STEM Major

Factors which contribute to choosing mathematics are examined in this study. Current research is rich with regard to students’ choice to leave the STEM majors. However, there is a dearth of studies, which focus on why students choose to pursue, or come to, the STEM majors (cf. Wang, 2012) and there are no known studies of students in elongated paths.

Hackett and Betz found math efficacy levels to contribute to science related college major choices (Betz & Hackett, 1982). Regarding the initial postsecondary experience of these students, “entrance into STEM fields was associated positively with intent to major in STEM, academic interaction, perceived adequacy of high school preparation for college, receiving financial aid, and expecting to earn a graduate degree” (Wang, 2012 p19). Interestingly enough, work demands, being a parent, receiving remediation, and enrollment status did not contribute to a significant degree to students’ entrance into the STEM fields (Wang, 2012).

Summary

Mathematical identity is not gained all at once after reaching a certain point. It is rather a structure which can be built upon, supported and reinforced with a number of different components. One’s efficacy, persistence, and other influential factors come together to support identity formation more generally, and mathematical identity in particular, as well as an ability to further build and maintain a mathematical identity. The research goals of this study, which are described in Chapter three, are pursued by examining how these contributors to identity are manifested in the lives of students who experience elongated paths.
CHAPTER THREE
METHODS

Research Questions

The main goal of this study is to identify and describe characteristics of mathematics students in elongated pathways to degree completion, so as to better understand how formations of mathematical identities occur. Specifically, this study aims to determine the following:

1. Are there themes or trends that exist among students in elongated paths, with regard to the students’ path type (Continuous/discontinuous, straight/winding), self-efficacy, mathematical efficacy, disposition, and factors which influence STEM choice and persistence?

2. What are the primary contributors to the formation of a mathematical identity for students in elongated pathways?

3. When do students report their first meaningful interactions in mathematics and does the timing of these interactions play a role in path length?

4. What factors reinforce, support, or maintain a mathematical identity and the development/formation thereof?

To pursue these questions both quantitative and qualitative methodologies were employed. Specifically, quantitative research techniques were used to identify particular characteristics of a larger population. In the section titled “Phase one: The survey” there are descriptions the population, survey instruments and analytic techniques used during the quantitative phase of the research. Since research on students in elongated paths is limited, quantitative techniques were employed to provide the depth necessary to
understand these students’ experiences. In the section, “Phase two: Student interviews, a phenomenological study” the population and instruments used in the qualitative portion are described, as well as the analytic methods for data collected.

**Potential for Bias**

We should not move forward without first addressing the potential for bias. I, the researcher and author, spent 10 years obtaining a bachelor’s degree in mathematics. I began my college career in remedial courses at a community college and explored several majors such as history, nursing, liberal studies, and theater. I did not experience periods of non-enrollment and received multiple associate’s degrees at my junior college. I transferred to a 4 year university, and changed my major to mathematics having only taken one calculus course. I graduated 4 years later and received a minor in the arts. Currently I am a graduate student in a mathematics program. I do not regret following a long road to mathematics but I often consider things which are hypothetical. Questions such as, what if I chose mathematics earlier? What if I followed through with any other major? I ask these questions because upon reflection I find it interesting to have chosen mathematics of all things, but I love it, and perhaps maybe it chose me. I wondered if others thought this way; that is, other students having elongated pathways to, or with, mathematics. And so began this research, which serendipitously converged to mathematical identities and their formation in an elongated path.

**Phase One: The Survey**

Participants for the study were drawn from a state-college which is acknowledged for its emphasis on the STEM disciplines. Mathematics majors at the college were given an invitation, via email and short recruitment presentations on campus, to participate in
the study by completing and online survey. Of the entire department of math majors invited to participate, 65 responded to the invitation by visiting the survey’s URL. Of the 65 respondents, 55 students completed the survey. These 55 respondents make up the sample population from which we gain local averages and other descriptive data. The survey was also used to identify possible candidates to participate further in the study (interviews-phase two). We will discuss the selection process for those participants in a later section.

Survey Participants

The sample population who completed the survey is made up of students who are currently enrolled in college. More specifically these students are majors, minors and graduate students in mathematics with either option (Applied/Statistics, Pure/Teaching). The purpose of surveying all of the mathematics students is to provide an accurate description of the program’s climate, i.e., what is generally typical of the students at the college? By including all students, we also create avenues through which to compare notions of efficacy, disposition and other frameworks outlined in chapter two.

Survey Measures

The survey consisted of 18 items and was comprised of multiple-choice, short answer and rated response type questions. The survey is presented in the appendix (see Appendix A). The first item was a consent agreement. If the anonymous participants did not attend to item one, then that data was discarded and not used. Items 2-6 were used to determine whether or not the student is a mathematics major, minor, or double major, graduate or undergraduate, and which program option they chose. Items 7-10 are concerned with path length and type (continuous, discontinuous, linear, or winding).
Items 11 and 12 have to do with multiple academic interests and ask the participant to provide information about other majors explored in their academic career. Items 13 and 14 offer a series of statements regarding both the student’s high school and college experience. Participants were asked to rate, on a scale of agreement (strongly disagree-strongly agree), statements about self-efficacy, mentors, persistence, co-curricular involvement, and choice of elective studies. Items 15 and 16 ask the participant to list mathematics topics or courses in which they feel they have excelled, and conversely ones in which they felt less confident. Item 17 was an open ended question for which the participants could provide a written response regarding their experience in a mathematics program. Item 18 was concerned with a willingness to further participate. Participants were able to leave contact information if willing further participate with the study. Of the 65 respondents, 55 completed the survey, including the consent agreement. Data gathered from the 55 respondents will be presented in the results section.

**Additional Analytic Methods for Phase One**

Survey Items reached beyond the scope of this work, however, each item was viewed as having the potential to reveal possible trends, themes and other descriptive information. Survey participants were asked to address certain questions regarding self and math-efficacy. With an agreement scale, students rated two statements (survey items 13-14) related to their mathematical abilities. The statements are almost identical, “I was…” versus “I am confident in my mathematical abilities”. These statements were used to measure the extent to which students felt confident mathematically, both during years spent in secondary school and in college. In this case the interest is in efficacy levels, before and after enrolling in college, of the larger population. We can then
compare that data to the data of students in elongated paths.

Efficacy statements in items 13-14 were accompanied by others which address identity as well. Again the students are asked to rate with agreement statements regarding aspects of their academic path. Aspects included were the levels at which mentors played a role in their success, to what extent did and do they pursue coursework outside of core curriculum, and if they view themselves as hard-working students.

Statements pertaining to mathematical identity were assumed to be present in item 17 (short answer response) of the survey as well. Item 17 asked students to provide information from their perspective about being a mathematics student, comparing themselves with peers, and contributors or hindrances to success. These submissions were coded by response type in order to identify trends and will be presented in the results section.

**Identifying Interview Participants**

A primary function of the survey was to identify possible participants for phase two of the study (interviews). Survey Items 2-10 revealed (a) whether or not the student was pursuing undergraduate or graduate studies, (b) how long the student had been enrolled in college, and (c) which path type was characteristic of the student. From this information the researcher was able to categorize students who wished to participate further (those who left contact information for item 18). These categories were designed to ensure diversity among potential interview participants. For instance, it was important to highlight students in different path types if at all possible.
Phase Two: Student Interviews, a Phenomenological Study

The aim of the qualitative portion of this work was to conduct a phenomenological study of students in elongated paths to mathematics degrees. “Whereas a narrative study reports the life of a single individual, a phenomenological study describes the meaning for several individuals of their lived experiences of a concept or a phenomenon” (Creswell, pg.57-58). The goal of a phenomenological study is to capture the “universal essence” of a shared experience from a first-hand point of view (Creswell, pg58). What is hoped to have been captured in the current study is the essence of a journey either to or with mathematics, in an academic path (post-secondary) lasting longer than 6 years.

Interview Participant Selection

Students who were interviewed for the study either were selected from the population of survey participants or were invited to participate via short recruitment presentations. Criteria considered for interview participants, which was self-reported in the survey or in person, included the willingness to further participate, length of time on academic path and the nature of their path (continuous, discontinuous, straight, winding). Students in all forms of trajectories were considered. That is to say that transfer status, age of first-time enrollment, and other such conditions did not contribute to the selection process.

There was an assumption that the interview sample might be significantly smaller than that of the survey. For this reason, certain steps were taken to increase the sample size, and in turn provide a richer body of perspectives for interviews. Undergraduate students in their 7th year or further were considered, as they could speak to their
experiences in-the-now. Students at the graduate level, who exhibited an elongated path to degree completion (bachelor’s), could provide a reflective outlook regarding their experience. Students in their 5th-6th year who are likely to engage in an elongated path, due to the number of courses remaining, could offer both a current and projective perspective. Allowing some variance around the time to degree completion allowed for a multi-angled perspective of the phenomenon.

Of the 55 survey respondents who completed the survey, 21 left contact information to further participate. Of those 21 students, 6 were considered, and asked to meet the researcher for an audio recorded interview. One other student volunteered to participate following a short recruitment presentation. These students were considered because they experienced (graduate) or were experiencing (undergraduate) an elongated path to degree completion. If a larger sample of candidates had emerged, other factors would have been considered in the selection process. Six of these students agreed to meet and participate in the interview process. Data from all six of the interviews will be presented as case studies in chapter six.

**Interview Design**

Student interviews consisted of 14 open ended questions, or prompts, to which participants responded. The interviews were audio recorded and selected segments were transcribed by the researcher for analysis. Interview questions were designed to touch upon the frameworks outlined in chapter 2. The scope of the interview questions was wide, as it was for the survey, and was designed as such to provide ample opportunities for students to provide and reinforce their perspectives as to why they are following or followed an elongated path to degree completion. A list of interview items is provided.
1. Is your academic path continuous or discontinuous? If discontinuous would you mind sharing why you experienced periods of enrollment and non-enrollment?

2. Would your academic path be considered linear, working towards one specific program, or winding? If winding would you elaborate on different majors you explored before converging to mathematics.

3. Please describe for me your math-history. In other words how did you come to be where you are today mathematically? Start as far back as you like, think of your first meaningful interactions with mathematics, and describe how you feel you have arrived at the current point in your academic path.

4. How long after enrollment, in your first college course, did you choose mathematics as a major? Further, what factors contributed to that choice. Were there support systems in place which facilitated your “choosing mathematics” or perhaps you independently developed an interest in the subject. Perhaps both or maybe something all-together different. Please elaborate for each statement.

5. What role have mentors played in your math-history, or in your success in mathematics?

6. What can be said about the role of peer groups? What about family support?

7. As of now, are you confident in your ability to adapt to new mathematical concepts given enough time and resources? Has this confidence, or lack of, always been present, or is it something that developed over time?

8. Have there been courses which were significantly difficult for you? To contrast, which courses do you feel you have excelled in? Can you speak to how you have
dealt with challenges or difficulties in your mathematical pursuits?

9. What other academic subjects are of interest to you? Are there other subjects of interest in which you explore with the passion and/or rigor with which you explore mathematics?

10. Have your electives been chosen to support or to contrast your major? What is the rationale for choosing elective as you did?

11. Which type of career are you expecting to pursue (academia, industry, etc.)?

12. Do you plan to persist further in your education? Are there plans of graduate school or PhD programs? Have you considered the field in which you might pursue further studies?

13. Please share how it is you perceive yourself as a nontraditional student within your mathematics program.

14. Are there other factors which affect or attribute to your struggles and successes in mathematics or any other information which you would like to share as pertains to your journey as a student? Perhaps there is more that you would like to share or that I am not asking you.

**Analytic Methods for Case Studies**

The intention of the case studies is to develop accounts, which might highlight characteristics pertaining to an elongated path and the formation of a mathematical identity. Throughout the interviews, there were recurrent statements and accounts which attended to issues of efficacy, dispositions, persistence factors and other frameworks as they pertain to mathematical identity.

To add structure to the case studies, the students’ experiences were framed and
will be presented in terms of the students’ precollege accounts and information, and then
the participant’s college years, with an emphasis on the point at which mathematics was
chosen by the participant. In addition to these three aspects, the presentation of the cases
was structured to highlight significant instructor or mentor interactions. Lastly, the case
studies focus on the challenges, or roadblocks in the students’ paths towards a degree in
mathematics. There was a specific interest in how the participants met or overcame such
challenges, as well as the factors which contribute to those challenges. The interview
questions were designed with intent to gather accounts relative to the critical constructs
outlined in the previous chapter, and in presenting the case studies, there is a focus on
issues or topics which continually arose, or were emphasized in the interview data.
CHAPTER FOUR

RESULTS PHASE ONE (SURVEY)

In order to pursue the phenomenological aspect of this research, it was first important to gather descriptive data about the larger population of mathematics students and to identify possible candidates for the student interviews. The online survey was utilized to achieve this goal. First, we outline the student sample population in general, i.e., how many majors, minors, graduate, and undergraduate students are there, and what program option are they in? Second, we examine how many years the students have been in college, and what type of academic path is present? The next item addressed is the high school-college comparisons (rated scale with statements regarding efficacy, mentors, etc.). Lastly, the responses to survey item 17, a short response open ended question, are presented. The six case studies will follow the presentation of survey data in chapter 5.

The Sample Population

The electronic survey was completed by 55 students. In the following, we share general characteristics of the respondents; namely, the student status (graduate or undergraduate), program option, major(s), minor, length of enrollment, and year that math was chosen as a major. In addition specific information regarding path type was gathered and is shown in table 4.1. The Path Types explored were discontinuous straight (DS), discontinuous winding (DW), continuous straight (CS), continuous winding (CW).
General Overview

Over 67% of students in the sample claim undergraduate status while over 32% claimed graduate. The majority of the sample is comprised of undergraduate students. The sample population is roughly split between students in either option. That is, between the applied/statistics option (54.55%) and the pure/teaching option (41.82%).

The majority of the sample did not expect to receive a minor or double major (60.09%). A small percentage of the sample (5.45%) claimed a double major and over 25% claimed a minor. It might be the case that elongated paths are exhibited because of the added coursework that a second major or minor creates. If double majors and minors exist in the small sample (phase two) we can then situate them within the larger population.

Over half (60%) of students in the sample have been enrolled from 0-5 years. The remaining 40% is roughly split between 5-6 years (14.55%), 6-7 years (9.09%), and 7+ years (12.73%). The part of the sample, who were considered as possible candidates for phase two of the study, were those that were in their 6-7th (9.09%) or in 7+ years (12.73%). Note that 7+ years is intended for graduate and undergrad students. Thus, some of the population will have completed their bachelor’s degree in less than 7+ years. The consideration to include graduate students was to accommodate the section in the methods chapter about widening the range for candidates to move to phase two. If a graduate student was enrolled for 7+ years then it was possible that they exhibited an elongated path, as was the case in three of the case studies to follow.

Choosing to pursue math upon enrollment was most common choice among students in the sample with 36.36% choosing math at this time. If we look at a larger span
of time, a large portion of the population chose math in between year two and three (34.55%).

In regards to path type, the largest percentage of the population claimed to have a continuous straight path (38.18%). The second largest percentage was continuous winding (36.36%). Together these populations show that a large part of the population has a continuous path versus a discontinuous one (see table 4.1).

<table>
<thead>
<tr>
<th>Path type of the sample population</th>
<th>Responses</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous winding</td>
<td>20</td>
<td>36.36</td>
</tr>
<tr>
<td>Discontinuous winding</td>
<td>4</td>
<td>7.27</td>
</tr>
<tr>
<td>Continuous straight</td>
<td>21</td>
<td>38.18</td>
</tr>
<tr>
<td>Discontinuous straight</td>
<td>3</td>
<td>5.45</td>
</tr>
<tr>
<td>Reported winding only</td>
<td>1</td>
<td>1.82</td>
</tr>
<tr>
<td>Left answer blank</td>
<td>1</td>
<td>1.82</td>
</tr>
</tbody>
</table>

A More Specific Categorization

In addition to the general characteristics presented above, the next set of tables focus more narrowly on the survey population. Tables 4.2-4.7 provide specific program option information, length of enrollment, and the year math was chosen for undergraduates and graduates separately.
Table 4.2

*Undergraduate program/option*

<table>
<thead>
<tr>
<th></th>
<th>Responses</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applied/statistics</td>
<td>20</td>
<td>54.05</td>
</tr>
<tr>
<td>Pure/teaching</td>
<td>15</td>
<td>40.54</td>
</tr>
<tr>
<td>Not chosen/left blank</td>
<td>2</td>
<td>5.41</td>
</tr>
</tbody>
</table>

From table 4.2 we see that over half of the undergraduate students are in the applied mathematics program. The remaining percentage is in the pure option (40.54%). Keep in mind that one student had not chosen yet and another did not answer the question.

Table 4.3

*Undergraduate path length*

<table>
<thead>
<tr>
<th></th>
<th>Responses</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5 years</td>
<td>17</td>
<td>45.95</td>
</tr>
<tr>
<td>5-6 years</td>
<td>5</td>
<td>13.51</td>
</tr>
<tr>
<td>6-7 years</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>7+ years</td>
<td>1</td>
<td>2.70</td>
</tr>
<tr>
<td>Not chosen/left blank</td>
<td>2</td>
<td>5.41</td>
</tr>
</tbody>
</table>

A bulk of the undergraduate population (45.95%) has been enrolled 0-5 years. Of those students, a majority reported to have chosen mathematics upon their enrollment in college. This was the most common time of choice among the undergraduate population as seen in table 4.4.
Table 4.4

*Undergraduate year math was chosen*

<table>
<thead>
<tr>
<th></th>
<th>Responses</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upon enrollment</td>
<td>16</td>
<td>43.24</td>
</tr>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt; year</td>
<td>5</td>
<td>13.51</td>
</tr>
<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt; year</td>
<td>6</td>
<td>16.33</td>
</tr>
<tr>
<td>3&lt;sup&gt;rd&lt;/sup&gt; year</td>
<td>5</td>
<td>13.51</td>
</tr>
<tr>
<td>4&lt;sup&gt;th&lt;/sup&gt; year</td>
<td>1</td>
<td>2.70</td>
</tr>
<tr>
<td>5&lt;sup&gt;th&lt;/sup&gt; year</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6&lt;sup&gt;th&lt;/sup&gt; year</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>7&lt;sup&gt;th&lt;/sup&gt; year or later</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Left answer blank</td>
<td>3</td>
<td>8.10</td>
</tr>
</tbody>
</table>

For the undergraduate population, math was again most often chosen upon enrollment, however, the competing span is now from years 1-3.

Table 4.5

*Graduate student program/option*

<table>
<thead>
<tr>
<th></th>
<th>Responses</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applied/statistics</td>
<td>9</td>
<td>50</td>
</tr>
<tr>
<td>Pure/teaching</td>
<td>9</td>
<td>50</td>
</tr>
</tbody>
</table>

The students in the graduate population are split evenly between both the applied and pure options.
Table 4.6

Graduate student path length

<table>
<thead>
<tr>
<th></th>
<th>Responses</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5 years</td>
<td>3</td>
<td>16.67</td>
</tr>
<tr>
<td>5-6 years</td>
<td>3</td>
<td>16.67</td>
</tr>
<tr>
<td>6-7 years</td>
<td>5</td>
<td>2.78</td>
</tr>
<tr>
<td>7+ years</td>
<td>6</td>
<td>33.33</td>
</tr>
<tr>
<td>Left answer blank</td>
<td>1</td>
<td>5.56</td>
</tr>
</tbody>
</table>

The largest percent of graduate students claimed enrollment for 7 years or longer.

Recall that the survey asked students to report the years in college since first-time enrollment at a postsecondary institution.

Table 4.7

Graduate year math was chosen

<table>
<thead>
<tr>
<th></th>
<th>Responses</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upon enrollment</td>
<td>4</td>
<td>22.22</td>
</tr>
<tr>
<td>1st year</td>
<td>2</td>
<td>11.11</td>
</tr>
<tr>
<td>2nd year</td>
<td>3</td>
<td>16.67</td>
</tr>
<tr>
<td>3rd year</td>
<td>5</td>
<td>27.78</td>
</tr>
<tr>
<td>4th year</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5th year</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6th year</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>7th year or later</td>
<td>3</td>
<td>16.67</td>
</tr>
<tr>
<td>Left answer blank</td>
<td>1</td>
<td>5.56</td>
</tr>
</tbody>
</table>
A larger percent of graduate students (27.78%) chose mathematics in year 3. The second most reported time of major choice was upon enrollment (22.22%). There were equal numbers of students in the graduate sample which chose math in year two and year seven or later (16.27%).

**Population Summary**

The above categorizations should highlight the diversity of the sample population. There are students in all program options, path types and path lengths in the sample population. One should notice, in the overview of the data, that approximately 21.82% of students (graduate and undergraduate) have been enrolled in college 6 years or longer since first-time enrollment. This figure includes graduate students and so there is a need to more specifically categorize.

If we focus solely on undergraduate students, there was 1 student out of 37 who reported having been enrolled in college beyond 6 years. Within the sample population it appears that the phenomenon studied in this work is not very common. More common in the sample population is a path of 0-5 years (60%). It may be the case that many of the respondents are in their first few years of their college path, and it cannot be determined how long after 5 years they might continue their studies. This is because the range of 0-5 years is too wide to determine how far before 5 years they have been in their college path. The other 40% of students are spread out among 5-6 years (14.55%), 6-7 years (9.09%), and 7+ years (12.73%) since first-time enrollment in college.

Path type was also highlighted in the overview data. A majority of students reported having a continuous path. That data was split between continuous-straight paths (38.18%) and continuous winding paths (45.45%). Approximately 12.72% of students
reported discontinuous paths, and again the data was split with 5.45% discontinuous-straight and 7.27% discontinuous-winding. The case study participants will later be situated within this data. Note that not all of the interview participants completed the survey and thus were recruited through presentations.

The time in which mathematics was chosen as a major is outlined as well. We are able to generally compare the interview participants’ time of choice with that of the entire population. This will be done in an introduction to the case studies.

**Agreement Scale**

Survey respondents rated statements regarding their high school and college experiences. There were a total of 5 statements. However, as mentioned in the methods chapter, the scope of the survey was wider than necessary and only 3 of the statements, along with the responses, will be shown. Response types and percentages are given in table 4.8 on the following page.
Table 4.8

Agreement scale data

(SA=strongly agree, A=agree, N=neither agree nor disagree, D=disagree, SD=strongly disagree, B=answer left blank)

<table>
<thead>
<tr>
<th></th>
<th>SA</th>
<th>A</th>
<th>N</th>
<th>D</th>
<th>SD</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High school</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. I was confident in my mathematical ability.</td>
<td>21</td>
<td>15</td>
<td>4</td>
<td>10</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>38.18%</td>
<td>27.27%</td>
<td>7.27%</td>
<td>18.18%</td>
<td>3.64%</td>
<td></td>
</tr>
<tr>
<td>2. Mentorship was essential to my success.</td>
<td>6</td>
<td>17</td>
<td>11</td>
<td>9</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>10.90%</td>
<td>30.90%</td>
<td>20%</td>
<td>16.36%</td>
<td>18.18%</td>
<td></td>
</tr>
<tr>
<td>4. I was involved in many co-curricular activities (clubs, study groups, athletics, etc.).</td>
<td>9</td>
<td>18</td>
<td>7</td>
<td>8</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>16.36%</td>
<td>32.72%</td>
<td>12.72%</td>
<td>14.55%</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td><strong>College</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. I am confident in my mathematical abilities</td>
<td>19</td>
<td>25</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>34.55%</td>
<td>45.45%</td>
<td>7.27%</td>
<td>1.82%</td>
<td>5.45%</td>
<td></td>
</tr>
<tr>
<td>2. Mentorship is essential to my success</td>
<td>16</td>
<td>21</td>
<td>8</td>
<td>2</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>29.09%</td>
<td>38.18%</td>
<td>14.55%</td>
<td>3.64%</td>
<td>9.09%</td>
<td></td>
</tr>
<tr>
<td>4. I am involved in many co-curricular activities (clubs, study groups, athletics, etc.).&quot;</td>
<td>5</td>
<td>10</td>
<td>11</td>
<td>18</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>9.09%</td>
<td>18.18%</td>
<td>20%</td>
<td>32.72%</td>
<td>14.55%</td>
<td></td>
</tr>
</tbody>
</table>
As seen in table 4.8, while a majority of students disagreed with statement 1 in high school, many now agree with the statement as it pertains to their college career. As for the role of mentors, there was a decrease in the responses from the neither to strongly disagree type and increase in agree-strongly agree responses. This shift happened as the sample of students shifted from high school to college. Co-curricular involvement did not increase from high school to college within the sample population.

**Survey Item 17**

Item 17 of the survey asked respondents to provide information regarding what it is like being a math major. There were repeated trends in the types of responses gathered and so categories were created to organize response types for descriptive purposes. Below is the prompt for survey item 17. An analysis of the data and descriptive results will follow.

Figure 4.9- Survey item 17

Survey item 17

From your perspective, what is it like to be a student in a mathematics program? How do you view yourself among your peers? Are there factors which hinder your success, or perhaps are essential to it?
Of the 55 students whose survey responses were considered, 11 skipped the question leaving a blank response. Consequently, the categorization of responses was developed from the 44 respondents who provided a short answer response to the survey item. The above responses were mined for data related to trending response types as well as predictors for success outlined in the frameworks section. Here we look to whether or not respondents attended to the following.

- Study groups as an attribute to success
- Utilizes office hours
- Mentors
- View themselves as greater than or equal in ability among peers
- View themselves with a lesser ability among peers
- Supportive faculty
- Positive academic community
- Appreciation for challenging coursework/program.
- Not feeling prepared for college.

Of the 44 respondents, 12 students (27.27%) mentioned study groups as an attribute to their success in mathematics. Examples related to this code include:

**Respondent #5:** It takes a lot of work to be a student in the math program, but it's a great experience. The professors are in general really great and the classes challenging. I believe I'm on the same level as my peers since we're all able to help each other out. Study groups are essential to my success.

**Respondent #15:** Study groups are essential to my success.
Respondent #19: It is hard being a student in the mathematics program. My study group is essential to my success. Time management has also become very important.

Respondent #27: I feel that an essential success to my math career has been study group. Collaboration doing HW was key to understand difficult concepts in my math career.

Respondent #28: I think being a math student was/is an eye opening experience. I always thought that if you were good at math you were a "nerd" or dorky. I learned from my journey that this is not the case I have met people who are "punk", skater, and from many other categories. I find myself as a very average math person I do not think I excel in math and for me to do well I have to work hard and invest time to do decent. Working with others to study was a huge part in my success.

Respondent #33: It was great because all professors were hands on and had passion in their teaching. Factors into success is to study hard, office hours, and group work.

Respondent #49: It means unending misery, thankless hours of work to understand abstract concepts- the applications of which are not readily apparent. I consider other majors jokes in comparison. I think that working in groups to review the concepts from class are critical to my success. I wish that we had a weekly mandatory group work session where we reviewed the lecture materials and discussed our problems, similar to format of MIT courses- ie they have lecture and then recitation.
Office hour utilization was mentioned by 2 students. Examples related to students’ views of office hours include:

**Respondent #6**: It is great being a student in the mathematics programs. A lot of peers are smarter than I am but I am hanging in there. Going to office hours is essential to success.

**Respondent #33**: It was great because all professors were hands on and had passion in their teaching. Factors into success is to study hard, office hours, and group work.

Only 1 student (2.7%) mentions mentors specifically as essential to success. Here is the statement related to mentors:

**Respondent #8**: Changing my major to math has been the greatest decision. Being in a mathematics program, there are always ways of challenging oneself and I enjoy that. The program has many students dedicated and enthusiastic about the subject just like myself, which makes it a great environment for me. On another point, I did not have much experience in high school with advanced math and sometimes that discourages me when I am with other peers that have the background. It makes me questions my potential at times. However, by surrounding myself with mentors and reaching out to the resources on campus I have been able to excel.

Twelve respondents (27.27%) reported as viewing themselves as equal to, or greater than, their peers in ability. Examples related to students’ views of themselves as equal to, or greater than, their peers include:
Respondent #1: To be in a mathematics program is quite challenging. You are expected to retain all the information you are given. Eventually however you end up doing more writing than computing numbers. I would say I’m average among my peers since not all mathematics comes easy to me.

Respondent #18: With math, one must always practice the concepts. I believe my peers and I are on the same boat, we need proper mentoring in the field of Math.

Respondent #14: I feel like I have a slightly better understanding of most of the material than some of my peers most of the time. I have a pretty good memory which helps me a lot in my studies. I enjoy math and wish others would too as I do.

Conversely, 8 students (18.18%) reported that they felt less capable than their peers.

Examples of statements relating to feelings of lower capability than that of peers include:

Respondent #4: I don't feel as smart as my peers, feel like I struggle a lot more.

Respondent #32: I like how everyone is easy-going. I hate to admit this, but I try to compare myself with others to see where I stand in the class. I believe this hinders my success, because I see how well others are doing in a certain class and wonder myself why I cannot do better than them.

Respondent #39: It is a terrible thing to be, non-stop thinking about problems and being at school from morning to night almost every day. I view myself as less than or equal to my peers. What my success depends on is my free time away from real life and social situations and filled with homework and studying.
Seven students, over 15%, made mention of supportive faculty. An example related to this code is:

**Respondent #43**: Being a student in the mathematics program is challenging, constantly in taking classes and keeping up with the pace of things. Compared to other students, I'm about average, or a little behind. Factors that definitely help success is professor availability, and friendliness. The approachability of professors helps to want to learn more and take studies more seriously.

There were 4 (9.09%) students who reported a positive environment or community.

Examples of statements related to environment or community include:

**Respondent #7**: I like being a Math major because I love Math. Everyone at the department is also really nice.

**Respondent #17**: The community is great. Small enough you feel included and diverse enough you can find friends. I feel like a lot of my peers are just trying to skate by and teach high school, which was frustrating as a Pure Math major who will not be going into teaching. Professors actually taking interest in my success is what really helped me. It's very empowering when you know the person who's gonna be teaching you and grading you wants you to succeed.

**Respondent #25**: I feel sooooo lucky to be a student in a mathematics program, especially [here]. Everyone is so friendly and willing to work with each other. I have definitely learned a lot, not only about mathematics but about how to be a good person. Factors that hinder my success are definitely if I don't eat or sleep well. And factors that are essential to my success are being on top of my homework and starting my homework early.
Seven students (15.90%) made a statement in regards to an appreciation for challenging coursework. Examples of statements related to challenging coursework appreciation include:

**Respondent #8:** Changing my major to math has been the greatest decision. Being in a mathematics program, there are always ways of challenging oneself and I enjoy that. The program has many students dedicated and enthusiastic about the subject just like myself, which makes it a great environment for me. On another point, I did not have much experience in high school with advanced math and sometimes that discourages me when I am with other peers that have the background. It makes me questions my potential at times. However, by surrounding myself with mentors and reaching out to the resources on campus I have been able to excel.

**Respondent #42:** Difficult but fulfilling - it is something that I am passionate about and I am always grateful that I switched from my first major. It is also a subject that I excel in so I am often the one that my peers turn to for help. The professors that I have had are definitely factors that have been essential to my success.

**Respondent #55:** Challenging but fulfilling, difficult but love the subject.

Two students (4.55%) made mention of feeling ill prepared for college coursework. Here is an example of a statement of ill-preparedness:

**Respondent #22:** Coursework is straightforward and consistent. Mathematically I felt prepared coming out of high school, but I didn't feel prepared to take on college or the real world as a whole.
Four respondents (9.09%) highlight some external challenges that students experience while also pursuing a degree in mathematics. These responses are listed below:

**Respondent #2:** As a young girl in the mathematics field, I think it is so amazing that I am able to choose such a hard, time consuming major. When it comes to viewing myself among my peers, I think we are about equal. I feel undermined when I am with them, like I don’t belong in this program I believe that one factor which hinders my success is my disease. I have [states disease] and because I have to restrict myself from physical activity, I have replaced it with mental activity. This makes me work and think harder than I would ever before.

**Respondent #16:** Being a student in a math program is stressful, challenging, has many moments of beautiful insight, creates many opportunities to make lifelong friendships, creates chaos in home relationships. As far as how I view myself among my peers: I am dependable in study groups, helpful to others. I don't think I am at the same level as my peers, and I appreciate their help in understanding the material and doing homework. The factors that hinder my success are problems and distractions at home (and they always happen during midterms and finals!) and at [work]. There is never enough time to perform all of my obligations to my satisfaction (at home, work, or in my classes). The factors which are essential to my success are study groups, support from family and friends (their encouragement can also be a source of pressure!), having a dog to pet at night is essential to countering the stress of the program and getting me focused.
Respondent #41: I feel like there are BRILLIANT people within my major and sometimes I even wonder how the hell I'm in the same class as them. I do feel confident in my mathematical skill set but there are people I feel are so much more intelligent and sometimes it can be demoralizing when there is a concept I have a hard time understanding and I don't see anyone else struggle with it but there are times when I'm able to solve a problem that they can't so it depends on the particular subject. I think each individual shines in different areas. For me the biggest hindering factor has been the fact that I've been going through a severe depression during my entire undergraduate career so there's an entirely separate battle going on within my own head that makes it a lot more challenging to even push myself to go to class or finish an assignment. Something that has been ESSENTIAL are group studies. When I meet people in my classes and we start to click, whether it’s just a duo or a group of us it helps incredibly to work together since we're able to pick each others brains apart and explaining the concepts helps in so many ways. If I'm able to explain and teach these concepts to someone else then it means I have a firm grasp on it.

Respondent #45: Being a student in a math program is challenging and exhilarating, but it can also be isolating. Math illiteracy is much more acceptable than reading illiteracy in our society. In general, people's attitude toward math is and their previous experiences are not always positive. As a result, there are few people outside the major who understand my motivations for continuing education in mathematics. Connecting with and working with other math students is essential to my success in the program.
There was no response type that was shared by an overwhelming percentage of students. The highest degree of shared responses were in regards to study groups and greater than or equal in ability statements at approximately 27%. These responses focused on the beneficial, and sometimes critical, role of working with others and on students’ evaluations of themselves in relation to others.

**Summary**

The sample population is diverse. Students are in varying stages of their academic career and chose to pursue mathematics at different times. We have some general information regarding mathematical ability, mentors, and co-curricular involvement for the sample in both high school and college. Finally, we gain a glimpse of the survey respondents’ perspectives and what is of importance to them with the response types for item 17. Together these components provide a broad description of the larger population from which many of the interview participants in phase two were selected.
CHAPTER FIVE

RESULTS PHASE TWO (CASE STUDIES)

The goal of the case studies is to provide the reader with information, and accounts, which will highlight attributes and contributors to (1) an elongated academic path in mathematics, and (2) the formation of each participant’s mathematical identity. Recall that this portion of the study is phenomenological. So the individual lived experience of each participant contributes to a description of the shared experience of the sample population. Interview participants were first asked to describe their math histories. These histories began with their first meaningful interactions in mathematics and end at the current point in their academic path. Supplemental questions were asked to provide opportunities for participants to elaborate further on those histories. Each case study has been separated into precollege and college experiences. Additionally highlighted will be the choice of mathematics, challenges or roadblocks, and significant interactions with mentors and instructors. Following each case study there is a summary with connections to the frameworks outlined in chapter 2. In conclusion, the case study data will be examined for commonalities.

Case Study: Cheryl

Cheryl began her college career almost 30 years ago. Her academic path to degree completion was both discontinuous and winding. Cheryl chose to major in mathematics approximately 20 years after her first-time enrollment to a post-secondary institution. She is now a graduate student and teaching assistant at the 4-year institution where her bachelor’s degree was awarded. Within the sample population 4 out of 55 students reported having a discontinuous-winding path. There were 18 graduate students in the
sample population and of those 11 reported enrollment, discontinuous or otherwise, beyond 6 years. This includes the sample’s graduate coursework. Of those students, 3 had reported choosing mathematics beyond 7 years of enrollment.

**Precollege**

Cheryl’s first significant interactions with mathematics happened at an early age. Her parents were educators and the notion of school was introduced as play. Cheryl’s enthusiasm for the subject continued as she was regularly ahead of her class in both primary and secondary school.

*Cheryl:* I am number four of five girls and my older sisters would come home and teach me. My parents were teachers and we had a chalkboard at home and so they would always play school with me. I still remember one of my favorite gifts from my grandmother. It was a book…I could do multiplication and it was exciting for me. I really like that numbers were always so consistent in the answers they gave.

*Cheryl:* In second grade I was beyond where the class was teaching, so they sent me to 3rd grade for math. And they wanted to skip me into 4th grade, but my mom refused to let them do that. In 7th grade I was at the top of the class and they asked me if I wanted to test into the algebra class. They had one algebra class for the 8th graders and so I tested and I got the high score. During that 8th grade class our teacher [female] enrolled us in a competition and we took 3rd place in [the region]. My friend and I did, both girls which was fascinating.

In high school Cheryl remained ahead of her class. She started in geometry and continued on an upward trajectory throughout her high school career. She also tutored
other students in mathematics reflecting her firm and continued understanding of the content.

In summary Cheryl’s parents were college educated and school was introduced as play. Her family was in support of education, and at an early age Cheryl exhibits traits of a productive disposition in mathematics. In junior high she was encouraged by a female teacher to pursue mathematics beyond the scope of the classroom. Cheryl continued to engage in mathematics outside of class as she tutored others in high school. Cheryl’s efficacy in mathematics appears to have been high throughout her precollege schooling.

**College and Discontinuity**

Following high school, Cheryl was accepted to a 4-year university. She had not yet chosen to pursue mathematics. She took two semesters of calculus at this college while attempting coursework in the field of engineering. After the two semesters Cheryl experiences a discontinuity in academics path.

**Cheryl:** I was a very good student, and was accepted with honors [to her first 4-year institution]. Engineering and problem solving seemed so fascinating to me…I got into my first engineering class and they assigned us…a simple project, they wanted us to draw, and when I got into my group they started talking about things that I didn’t understand. [They were] drawing solar-water-pumps for pools. That was not my understanding of what the project was, and I felt threatened, and I quit. So I dropped out of engineering the first quarter I was there because I didn’t have support and there weren’t a lot of women in that class, and I did not know who or where to go for help. After a year of just wandering around, I took some math classes there. I didn’t know what I wanted to do and my friends were all
seriously dating and getting boyfriends…I wanted to get married and have kids so I found someone and we got married, so I dropped out of school.

At this point Cheryl began to feel “overwhelmed” and “unsupported.” The engineering class felt too advanced for her. She also states that her parents were going through a divorce so there was not much support coming from home during this time.

Women Cheryl’s age (late teens early 20’s) were beginning to marry and have children. Cheryl followed this trend and did not return to college for 20 years. During this time she raised her children while also working at her family’s business.

Cheryl: When my oldest daughter was a senior in high school I started back in college because I wanted to go to college the same time as her. And then she finished her degree well before I even made it here.

A Return to College and Choosing Mathematics

Cheryl enrolled at a local community college where she would pursue courses in the field of business. Her entrance exam scores placed her in trigonometry, which is commendable after being out of school for 20 years. It is clear that after all this time she remained strong in mathematics. The choice to pursue business seemed appropriate as she had maintained a substantial position at her family’s business in the years prior.

Cheryl completed an associate’s degree in business, and was nearing transfer to a second 4-year institution. With her academic path seeming to converge, Cheryl serendipitously realizes something which would start her on a path towards mathematics. In 2008 Cheryl was introduced to a TV show called Numbers.

Cheryl: It was Superbowl Sunday. We were on vacation and we were watching…a new TV Show and it was called Numbers. And I saw that, and it reminded me how
much I love math and I was just completing my business degree [associates] and I realized that’s what I wanted to study. It just took that one show. So that was it. I enrolled in a math class…so yeah, I did love math, see?

In watching the show she remembered how fascinated she had been by numbers and patterns in mathematics. Her engagement in the show sparked something inside of her and she knew the path she truly wanted to follow. She stayed at the community college to complete as many math courses as they offered and transferred to a 4-year university.

The TV show was definitely a tipping point for Cheryl, however there are other factors which reinforced her decision to pursue mathematics. Cheryl had received some interesting news. The man she believed was her father was in fact not. She soon learned about family members that she had never met. Reaching out to them, they soon gathered to meet. Many members of this family were educated, and many pursued degrees and careers in the STEM fields. Cheryl felt a sense of belonging in this group and this further solidified her choice to study mathematics.

The family business was consolidated and there was no longer a need for Cheryl’s position. She took this opportunity to dedicate herself to school and be a full time student. She enrolled in 16 math units her first quarter which, as you can imagine, turned out to be quite challenging.

Roadblocks and Mentors

Cheryl’s confidence in mathematics, and in herself, was tested many times over her stay at the university. Thoughts of quitting again flowed in and out of her consciousness, as some of the advanced topics seemed to get the better of her. She stayed determined and persisted nonetheless. It was the influence of emerging role models and
supportive faculty which caused her to stay despite her intrusive thoughts. Cheryl reports an experience she had in an instructors office hours.

**Cheryl:** I entered [abstract algebra] where I wanted to quit, and [the instructor] was…let’s just say that I wouldn’t be here, I would not have continued on if he hadn’t just been supportive. He would be telling me to just go home and put my books away. Just stop thinking about math despite the fact that we had a midterm 3 days later. He said I don’t want you looking at your math today, put it away, go do something else. He was absolutely right, I needed to get away from it because I was so overwhelmed that I kept repeating, looking at the information and not absorbing it. But I was really ready to quit and there were students in his office and I was sobbing at the door, and one of them said oh I feel like quitting, and I said yep, that’s the thought I had as I walked up here. I should quit I’m not good enough, and that’s when he said just go home. So um…I stuck with it, I passed his class, I passed [the second section of this course], probably 2 of the most difficult classes I took because algebra and I, we’re not friends. But I’m gonna tackle it again, and I’m gonna own that!

**Peers**

In the survey data, specifically item 17, study groups were often reported as essential to success among the sample population. Cheryl sees value in study groups. Indeed, it appears that other students, and the formation of study groups, play role in Cheryl’s continued persistence.

**Cheryl:** First of all I know that they [other students] are all struggling, just like me. And oh! The study groups, the study sessions […] you know I provide support when I
think that they need it and sometimes they’re supporting me. It can be anything from you need to come down here and work on this homework with us, you know…I find that in return they are just as helpful. We all want to see each other succeed.

Cheryl graduated with a degree in mathematics, nearly 30 years after her first college course. Now, after only a couple of years, Cheryl is nearing the end of a master’s degree program and is a teaching assistant at her institution. She truly enjoys education and teaching, and will likely pursue a career in an academic setting.

**Summary and Connections**

The goal of this study is to identify and describe the characteristics of students who follow elongated pathways toward degree completion in mathematics. Further we want to understand the formation of the mathematical identities of these students. Let us first consider the factors which attributed to Cheryl’s college path and causes for elongation.

Cheryl had a strong interest in engineering and problem solving. She may have persisted further in this major but experienced a threat to her efficacy. This was a major factor for why she left college, “I felt threatened, so I quit.” The decision to leave school was further supported by pressures on Cheryl to conform to the social expectations of women of her generation. Familial interactions also played a significant role in Cheryl’s academic path. It was her family, when she was a child, who sparked her interest in mathematics and problem solving. Yet while at the university she lacked family support due to her parents going through a divorce.
Upon Cheryl’s return to college she pursued business. Her social and occupational status guided that choice. She spent time pursuing this major before choosing mathematics, which further elongated her path to degree completion.

The formation of Cheryl’s mathematical identity begins in childhood. Family interactions which placed emphasis in education and mathematics laid the foundation for her identity. Positive experiences in elementary and junior high school such as skipping grades and winning the regional competition add to the structure that is mathematical identity. Teachers were integral in reinforcing and helping to further build this structure. They did so by recognizing and encouraging Cheryl’s mathematical ability and providing opportunities for co-curricular involvement. Her identity is strengthened in high school as she was a student who was knowledgeable and capable of helping others in mathematics. She tutored others, showing strength in mathematics, and a model for productive educational practices.

It would seem that Cheryl has always had a predisposition to mathematics and problem solving. Even after a discontinuity and return to college, she shifts to mathematics for reasons beginning with affect (i.e. her emotive response to Numbers). Though predisposed to mathematics, Cheryl seems to have been easily deterred if her self or math efficacy were threatened. There were two accounts which speak to this phenomenon. In the first instance of efficacy threat, in the 1st year engineering course, she was unsupported by faculty, peers and family members. She soon dropped out of school completely. In the latter case, the abstract algebra class at the 2nd 4-year college, she had support in all three respects. These types of support lead to continued persistence in mathematics.
Case Study: Javier

Javier spent 8 years obtaining a bachelor’s degree and is currently pursuing graduate study in mathematics. He chose to pursue math in his 3rd year of college and his path type was continuous-winding. Of the 18 graduate students from the sample population, 4 chose mathematics as Javier did in year 3. There were 4 undergraduates out of 37 who reported choosing math in their 3rd year as well.

Precollege

Javier’s math history begins at a later point than that of the previous participant. He does recall performing well in elementary school however does not connect further with mathematics until college. This section is brief as he did not have much to report about mathematics precollege.

Javier: The one thing that I’ll always remember is that for elementary school, I was really good at my times tables, like super-fast. There was a point when I finished, the teacher’s like “you’re already done?” I’m like “yeah” everyone’s still doing their work, I’m like done. That was really cool [...] In high school I didn’t really put any effort into any class. That’s all around, except for PE.

College

Despite his indifference to high school Javier was not held back at any time and graduated with his peers. He began his post-secondary career at a community college where he was placed into an intermediate algebra course. Math was not Javier’s first choice of a major. He spent timed exploring others (history and philosophy) that interested him. Javier focused mainly on general education courses in his time at the community college.
Choosing Mathematics

Javier struggled with mathematics in early college but due to transfer requirements he would need to complete courses through college algebra. It is fortunate he did as it was this course that led to him choosing mathematics.

Javier: What really got me like towards math was during my last year at a junior college, I had to take my last math course for a GE, and actually a teacher, that was there, was what made me become a math major. Before I never had a teacher that presented the material like so good. And I was just like “I get it”. At that time I struggled with just like college algebra. That’s what I was taking. From there I just stuck to math and I just kept on going…That’s just when it clicked for me, when I decided to do math, so I stopped philosophy.

Javier speaks very highly of his algebra instructor at the community college. The instructor presented content in such a way that he had never experienced. “I don’t know how to explain it…he just presented the material in a nice way…the pace was just right for everyone in the class”. Javier felt as if mathematics and he were finally clicking.

Being inspired to continue further by his teacher, he pursued course after course in mathematics, claiming the major in his 3rd year. “I just wanted to see how far I could go”.

Continuing Education and Challenges

Before completing his undergraduate work, Javier was encouraged to participate in an REU program (Research Experience for Undergraduates). He was urged to do so by two instructors who knew him at the 4-year institution where he received his bachelor’s degree.
Javier: During my undergrad [...] at the time I was kind of interested in graduate school but I wasn’t sure about it, and um...These two professors asked me if I wanted to be in a REU program. And this all happened in my last year of college. So in my last year of college I did an REU program and I started learning about all these other options and that’s when I really became interested, you know, in going into graduate school now.

This experience influenced his decision to further pursue mathematics at the graduate level. Now being a graduate student, he had some words about persistence regarding his path at the master’s level which are also representative of the challenges of being an undergrad.

Javier: whenever I get a C or lower on the exam I always question myself [...] Analysis was the class where I kept saying, “Why am I a math major”. It’s like I could get C’s, I can’t get an A in this [...] I’m supposed to know what I’m doing at this point but no. And then I just keep telling myself [...] you know just keep on going. If I put myself down, like “why am I doing this?”, I always find a way to self-motivate. [...] I just keep on going [...] that’s crucial, at some point you just have to find a way to self-motivate.

Javier: The outside factors that just make me keep on going...well mostly it’s for my parents. So they know that I can do it. In my family, my oldest brother is the only one that has a masters, everyone else got bachelors. So I decided to be the next one to get the masters.
Summary and Connections

Javier exhibited a winding path in college where mathematics was not initially in his field of vision. His lack of interest in high school lead to his elongated path to degree completion. Having not expressed an interest in mathematics, nor any other subject specifically, it took some time and exploration to find his academic path once he entered college. Javier first started with history and then shifted to philosophy. He expressed an interest in these subjects but did not report significant reasons for pursuing them beyond being interested. As he pursued other general education coursework, Javier eventually found himself in college algebra. Many students view college algebra as a “gate-keeper” course as it fulfills requirements for university transfer. In other words, one must take college algebra or an equivalent class to satisfy general education requirements. In this class Javier became engaged in mathematics after having struggled through the prerequisite coursework. This was in his 3rd year at the community college. Javier’s math efficacy was on the rise and, wanting to see how far he could go, he engages in a steady path until degree completion.

Javier mathematical identity began developing in that very algebra course. The instructor presented the material in a way that he was receptive to. So the instructor’s presentation of mathematics created an opportunity for access. Once he gained access Javier’s path to degree completion became straight. With each class, seeing how far he could go, Javier was gaining strength in his mathematical identity and saw himself finishing a bachelor’s degree. He began to view himself as someone who would pursue graduate coursework when he was approached by supportive faculty to join an REU program. Gaining access to higher level topics and practices inspired him to pursue math
further, “…I started learning about all these other options and that’s when I really became interested, you know, in going into graduate school…” This pursuit has not been without challenges and Javier attributes his persistence in mathematics to internal and external factors such as his capacity to self-motivate and a desire to complete higher education like his brother.

Case Study: Andrea

Andrea is approaching her 7\textsuperscript{th} year in college. Her path is winding, as she explored multiple majors, and discontinuous with 1 semester of non-enrollment. She chose mathematics in her 4\textsuperscript{th} year at a community college and the transferred to a 4-year university. She will be graduating in the next academic year with plans to pursue a career in industry and perhaps graduate school as well. There were 4 out of 55 students who reported discontinuous-winding paths in the sample population. Of the undergraduate students, one student reported a path exceeding 6 years and only one student reported choosing math in year 4.

Precollege

Andrea reported that her first meaningful interactions in mathematics happened during childhood. She remained actively involved in mathematics throughout her secondary education and finished high school having taken AP mathematics courses. Andrea: I’ve always really liked math. I’ve always been a really good student. I remember in elementary school I was a little bit more advanced than some of the other students. So I urged my teacher to kinda do…like we called it “algebra club” I think in 5\textsuperscript{th} or 6\textsuperscript{th} grade, and we would stay in the classroom during recess and me and a few students would learn more math than the other students were
learning. Then when I got into junior high and high school I was always like in the more advanced math. So, I just…I would take…my senior year I took AP calculus and statistics. And yeah, it’s just something that always came easy to me, but like…I wasn’t a well-rounded student. The only AP classes I took were in math, and I enjoyed them.

Having completed her high school education it was now time to consider a college career. The road ahead was not clear. Nevertheless, Andrea moved forward in her academic path without discontinuity. Andrea’s parents were not college educated, however, they and she knew that attending college was the right thing to do after high school.

**Andrea**: My mom was like “you’re going to college”…there were certain periods in high school where I was like “I don’t think I want to go to college”. I was in sports so I was thinking for a second that maybe, you know, I would make it in my sport professionally and she [mom] was like “No! Even if you do make it professionally you need to go to college anyway”…for like a backup plan. So I was like eh…but once I got older, you know my senior year, I knew I needed to go to college. They [family] pushed me, you know they were really proud of me when I got in and to this day they’re still always asking me about school and everything. So I definitely was pushed to go to college and then supported throughout the process.

Andrea’s efficacy in mathematics was strong throughout her precollege experience. She chooses to learn math instead of taking recess in elementary school and felt she remained solid in her understanding of the subject through high school. Though
self-reportedly she was not a “well-rounded” student, Andrea finished high school strong in mathematics and completed AP coursework. Oddly enough, Andrea had not yet incorporated the subject in which she was most confident as part of her identity explicitly. There was not a clear plan as to what would happen next academically, but Andrea was supported by her family, and was convinced that she should attend college. After graduating she enrolled in courses at a local community college. Andrea explored many different majors before converging on mathematics.

**College**

**Andrea:** It was definitely a journey. I just realized that I wanted to do math about a year and a half ago, two years ago. I was pretty into cars and stuff growing up so I thought…uh for sure it [her major] would be mechanical engineering, so that’s what I started with. As I started getting into the engineering courses and science courses I realized I really hated science. Um…but I did like the math. So even though now I wasn’t sure what I wanted to do, I just kept taking all the math courses. Then I explored other stuff, just business cause that’s what everyone else was doing, but I didn’t like that. Nursing because I used to work for a doctor’s office and they were trying to push me to be a nurse. So I started that, I didn’t like that. And then every quarter when I was exploring the other majors I still always kept taking math courses because I enjoyed them. Until finally I realized why not just pursue math and math alone?

**Choosing Mathematics**

The choice to pursue mathematics came in Andrea’s 4th year of college. She realized that with each college major explored, her work in mathematics had not ceased.
Further she was doing well in the subject. Now begins the convergent portion of Andrea’s academic path.

Andrea: I know when I first started exploring the idea of majoring in mathematics, well you know, obviously I went to Google cause…I just don’t feel like in high school we were exposed enough to… like college life and the options that are out there for us. I don’t even think I realized that mathematics was like a choice, that you could major in just mathematics, until I started researching it on my own. So once I started researching that, and realizing the benefits and the job opportunities, and just how broad the opportunities were for math majors. That was kinda like, okay this is what I’m gonna do because you know there’s just a plethora of options after I graduate with this degree. So that was like my final…the last straw on making the decision to be a math major. Just knowing that there were so many opportunities once you graduate.

Admittedly, Andrea did not know math was a subject that one could major in. The subject had not, to her knowledge, been presented as a clear option. She did what most of us do when we are unsure of something nowadays, she Googled it. She found that mathematics itself was indeed a major, and one that provides a multitude of career opportunities. It seems that once she had realized the potential rewards or benefits of studying mathematics, beyond that of satisfying her interest in the subject, she begins to realize a path in which mathematics is the focus.

Roadblocks and Mentors

Andrea: My parents didn’t go to college. I have an older sister, she didn’t go to college.

So I’m the first one in my immediate family to go to college, so I was kind of
blind you know? I was a little timid. I wasn’t like very open to going to people and asking for help. I more just wanted to do it on my own because I was timid to ask others for help, which probably hurt me a little bit at the beginning because…I don’t want to say that I wasted time, but I feel like I wasted a little bit of time taking a bunch of courses I didn’t really need. But that was a fault of my own because I didn’t seek help from an advisor.

Andrea does speak of two influential characters in her path toward a degree in mathematics. It appears that, for Andrea, it is of important to connect, or feel comfortable with, instructors in order for her to allow them to mentor her.

Andrea: I guess like one of the first teachers I kind of…was more attracted to, was a woman I had at community college. She was just really personable so I just felt like I could talk to her more, and I guess she was one of… the first person I leaned on. And this was before I wanted to be a math major but…she was actually my calculus II teacher. So she was one of the first teachers that I really felt comfortable with. I wouldn’t say that she was really a mentor but just one of the first teachers I got close with.

Andrea: Now that I’m at [the 4-year institution], I lean on [a female instructor] a lot. She’s not my assigned advisor but I’m really comfortable talking to her. I’ve seen her a couple of times about different options after I get my bachelors and the field of operations research which I’m really passionate about. I’d say she’s been one of my mentors at [the institution].

This instructor inspired Andrea to pursue further (graduate) education in mathematics, and particularly in operations research, simply by discussing the topic itself
and the possibilities for growth. Andrea would first like to find a job in industry which offers some type of tuition assistance, then return to school to complete a master’s degree program specific to the topic.

**Summary and Connections**

Andrea’s path was elongated due a lack of guidance and preparation during the transition from high school to college. Andrea entered college because she was encouraged to do so by her mother. Beyond encouragement, her family could not offer the support she needed because Andrea was the first in her family to attend college. She spends 4 years winding through different majors before converging to mathematics, a subject she had enjoyed since childhood. This theme becomes recurrent as many of the participants showed high efficacy in precollege mathematics but were not encouraged to pursue the major in college. In turn these students spend time in other majors before converging on mathematics.

Mechanical engineering was her first major choice. This was because she had an affective interest in the subject stating that she “…liked cars and stuff growing up”. She says that she hated the science aspect of that major. It is unclear from the data whether or not this dislike arose from a threat to efficacy or simply a disinterest. She did however state that she still enjoyed mathematics as she had throughout her precollege experience. She then pursued business and nursing because of social and occupational positioning. For business she stated that “…that’s what everyone else was doing.” Andrea pursued nursing because she worked at a doctor’s office and was encouraged to do so by her coworkers. Again she became disinterested in those subjects. All the while she had taken courses in mathematics and was doing well in that subject.
Andrea stated that she felt there was a lack of preparation for college in high school, and did not know that one could major in mathematics. Had she known, it is possible that she would have pursued that which she had been interested in since elementary school. Rather than seeking resources on campus, Andrea uses the internet to gain information about the major. She reported that she wasted some time taking courses that she did not necessarily need. She blames herself for being too timid to seek an advisor for assistance. It is possible that had she spoke to someone early on, and expressed her interest in mathematics, that she might have entered the major sooner.

Now let us look to the factors which contributed to Andrea’s mathematical identity. Her first reports of meaningful interactions occur in elementary school. There was support and involvement by a teacher who engaged students in “algebra club” during recess. Andrea’s efficacy in mathematics was high throughout the rest of her precollege experience as she stated being ahead of her class and finishing high school in AP calculus and statistics. Her productive disposition in mathematics continues as she engages in mathematics coursework even though she was pursuing other majors. Upon seeking information on the internet, and realizing the opportunities mathematics had to offer, her academic path became clear. Her desire to obtain a college education and a substantial career finally aligned with a major that interested her. She reported having “leaned on” an instructor at the community college but it was an instructor at the 4-year university who inspired her continued education and identity in mathematics.

In Andreas case there is an aspect of teacher involvement which contributed to her mathematical identity, but also it seems that she herself played a significant role. The teacher in elementary school supported her, and other students, in a further exploration of
mathematics, but she also maintains momentum on her own. She does not report anyone pushing her to take mathematics in college, rather she does so by her own volition. She independently seeks information about job opportunities in mathematics and switched majors and the instructor/mentor at the 4-year university contributes to Andrea’s goals beyond degree completion. Again this aligned with her interest, for Andrea enjoyed operations research and this instructor provided information about job opportunities and continued study in that focus.

In summary, Andrea’s driving force is her productive disposition in mathematics. A lack of proper preparation for college, both systemic and familial, caused her educational path to become elongated. Her inability to seek institutional resources, or possibly the lack of intervention on the part of the institution, further elongated that path. Notice that her next steps, after degree completion, are much clearer than those of her transition to college. It would seem that the cause for this is instructor-mentor involvement, and the discussion of viable options prior to degree completion and transition to the work force and graduate school.

Case Study: Mark

Mark is a graduate student in a mathematics program. He began his postsecondary academic career at a community college, chose math in his 2nd year and completed a bachelor’s degree program with a double major in 10 years. There were 3 graduate students out of 18 and 6 undergraduates out of 37 to report choosing math in their 2nd year. Of the sample of graduate students, 2 out of 18 double majored as undergraduates. Mark’s undergraduate path was continuous and winding which was experienced by a majority of the sample population.
Mark’s first memorable interactions in mathematics happen in junior high. He first recalls almost failing pre-algebra. Positive experiences with the subject are present when he reaches high school and beginning with humor, we will see the forming of Mark’s mathematical identity.

Mark: Nothing stuck out in my elementary times, nothing stuck out, it was just, you’re going to school, no big deal. Junior high…I took pre-algebra. Let’s see, I was in basic remedial math my 7th grade year. My 8th grade year I almost failed pre-algebra. When I went to high school I almost failed pre-algebra again, and actually the teacher was refusing to push me forward because she thought I was…not mature enough to handle algebra 1. After debate and everything else, she finally signed the paper. When I took algebra 1, and this was probably my first inspiration, it was actually a P.E. coach, and when he was teaching, everything made sense. I was doing the homework in advance because he had a syllabus and there were pre-assigned homeworks and I was 3 weeks ahead in class. He made it entertaining. One moment was when he threw a wooden ball at one of the students because he was talking, and that was hilarious. Pretty funny... it almost hit me. And that was my first moment that I realized that you could have fun with this subject, you know, just have fun with it.

So after years of non-engagement and near failure, mark found his algebra teacher to make sense. Further he found him to be humorous, as he seemed to have fun with both the students and the subject. Mark experienced a rise in math-efficacy and had an affective connection to the teacher, and so began to engage in educationally productive
practices such as looking to the syllabus and doing homework in advance. Mark was more receptive to his next teacher and class content and continued to make progress. He maintained a steady trajectory and finished high school in an honors algebra and trigonometry course.

Mark: So when I went to geometry, this other teacher that I had did a really good job at teaching geometry, and I had…I really started enjoying mathematics…to a certain degree, but still not aware of it. Then I got into honors algebra and trig my senior year and really started enjoying it, but still not waking up to it, like hey this is what you need to do. It wasn’t until college, or junior college, That I’m like “okay”, I just reflected over where I wanted to be, where I thought I wanted to be, and what I was naturally good or descent at. I stuck with mathematics and that’s what I did. I got my associates degree in mathematics and then came to [the four year institution].

Mark enjoyed mathematics in high school but did not initially pursue the subject upon enrollment to a postsecondary institution. He spent two years pursuing an art degree before “waking up” to mathematics.

College

Like many participants, Mark enrolled at a community college. His parents did not attend college but urged him to do so. Mark did create a path for himself but it was not without its challenges.

Mark: My parents told me that I need to get an education. But there was really no direction and there was really no guidance in how to pursue that because my parents at the time, didn’t have, um, a college education. They had a high school
education. So the financing and applying for loans and all that stuff didn’t make sense to them and they said that…figure it out on your own.

Mark figured out the financial matters and entered the community college. He continued to take math courses even though his initial intent was to pursue art and focus on computer graphics. Early in this academic path (year 2) he started to realize that he had a “natural ability” in mathematics. His choice to pursue mathematics occurred during a graphics course in his second year.

**Choosing Mathematics**

**Mark:** I originally stared as an art major. I wanted to focus on computer graphics.

Computer graphics design is where I wanted to go, so an art degree would be where I wanted to go. Then I found that I had a natural ability in mathematics and I sucked at programming at the time so I decided to change into mathematics […] I reflected on that, I couldn’t do Java, but wait, I’m in calculus II… you know what, maybe mathematics is the way to go.

Mark continued his coursework at the community college until he transferred to a 4-year institution with an associate’s degree in mathematics. Upon doing so he had to choose a major and focus. In honesty, he reports that he was unsure of what the different program options entailed. “I just closed my eyes and randomly picked” declaring applied mathematics with an emphasis in statistics. Mark pursued applied coursework, but did not engage in the statistics sub-plan. Instead he found himself interested in engineering. This interest led him to pursue a double major and in turn experience a longer path to degree completion. He finished college nearly 10 years after his initial enrollment with a degree in both math and engineering.
Roadblocks and Mentors

When asked about mentors Mark revisits the two teachers he had in high school. These were the people that made mathematics meaningful in a positive way. Had it not been for their teaching philosophies and mathematical insight, he may not have seen the value in mathematics at this time.

**Mark:** My inspiration really was to the two teachers I had in high school, and the way that they made mathematics interesting instead of the drawn out, boring like just “plug and play”, this is what you need to do, just no entertaining factor in it, no humor. I started correlating that with mathematics, and I noticed if I started having fun with it, it’s more engaging. Because mathematics can be extremely boring, but try to make it entertaining, it actually works out pretty nice.

Mark states that he did feel supported in his work at the four-year institution (where he was a double major). He took 7 courses with one influential instructor who served as a mentor and another facilitated his path as an advisor would, who helped him determine how to complete coursework for both majors. Following the path of a double major kept him at the college for a longer length of time.

**Mark:** In regards to me completing my degree...There are two professors that stick out the most at [the institution] [...] I had 7 classes with [the first instructor] so it’s easy to see how we became really good friends, and he was actually a kind of...a person I can lean on and talk to about stuff. [The other instructor] [...] In regards to me completing my engineering degree [...] which I should tell him “thank you”...but, when the economy took a dump in 2008 [the institution] got really tight with their budget in 2009 and decided to [force seniors to graduate]. I had over [the max
units] and they would have wanted to kick me out. Luckily enough, I was an applied-stats major without completing all of my classes. So me closing my eyes and randomly picking a sub-plan actually helped out, really good. That saved me from getting kicked out and completing both degrees.

The second instructor advised Mark as to how he might use the fact that he never changed his sub-plan to his advantage. Had it not been for this instructor’s guidance, Mark feared he would have been forced to graduate early with only one major.

When asked about challenges outside of coursework, Mark shared an unexpected aspect of his academic journey. On two separate occasions, once for a week and the other for 9 months, he was homeless while attending classes at the four-year institution. Lacking adequate financial assistance Mark had to choose between his essential needs and his college pursuits. In the second case, Mark remained without a home for 9 months. This is a full academic year. The choice, to him, was simple. He chose to forego having a safe place to call home in exchange for coursework which would complete his degree requirements for both majors.

Mark: I’ve been homeless twice since I’ve gone to [the university] [...] I chose to use my rent money in order to pay for my last class [...] So I sacrificed 9 months of sleeping in my car to do that. [...] Financial aid...I was under the age where you’re declared as an independent so I think I got [a smaller than needed amount of money] for the entire year. [...] A lot of rice, or not eating at all haha. So yeah that was a major hurdle [...] I mean trying to do analysis and the proofs was terrible in itself but outside of that ...yeah, but it’s all due to finances, I couldn’t afford
school. So you eat rice for 3 months then make it spicy, throw some beans on it...that was a luxury.

Beyond a predisposition in mathematics, Mark saw value in completing his degree. It seems that he was willing to risk more than most in order to finish school. This is significant in that he is attached to the identity of a college graduate, and actively sought to obtain his degree despite the significant cost.

Mark: I’m almost done. I invested this amount of money and I’m not going to throw away that money. Basically I could have stopped and done my bull-crud job [...] It was something that I had to do, and the payoff is substantially huge. So that little bit of sacrifice is nothing compared to my lifespan.

Mark’s determination paid off. After graduating he was offered work in the field of engineering and later returned to the institution for graduate work in mathematics. He is on track to complete the master’s program and hopes to further pursue a career in industry with an expressed interest in aerospace engineering.

**Summary and Connections**

Mark experienced a winding road his first two years of community college. He also acquired a second major after transferring to a 4-year institution. These are the main causes of his elongated college path. Let us consider why Mark’s road was winding. Mark became productive in mathematics early in high school but chose art when he entered community college. This becomes a recurrent theme. That is, students who perform well and are partial to mathematics are not being encouraged or persuaded to pursue the subject in college. There is then an exploration of other subjects which
eventually converges to mathematics. This was the case for Mark, as well as other participants.

Teachers appear to be the most influential in Mark’s mathematical identity formation. Mark’s first meaningful interactions with mathematics were in high school where he was affectively engaged by the humor and clarity of his algebra teacher. He was fortunate enough to have an engaging teacher to follow in geometry. From this point on, he built momentum in mathematics and finished high school with honors algebra and trigonometry. Once his math efficacy was raised, in path through a connection to the teacher and the material, he began to engage in academically productive practices. Mark remained engaged in mathematics, just as Andrea did, while pursuing the graphic arts coursework and by doing so he was maintained a mathematical identity even though math was not his major.

He was mentored at the university by two instructors. One of which he is now friends with, and with whom he took numerous courses. Mark also sought guidance from an instructor and advisor figure to negotiate the terms of the double major; that is, to discuss how to use his sub-plan option to complete the units left in the second major of engineering.

Mark plays a role in his own identity formation. He remained persistent and even willing to forego housing and food to finish his undergraduate coursework. He was willing to risk these essentials in order to experience the “substantial” rewards that his degree would provide. By doing this Mark was aligning himself with where he wanted to be in regards to his education and future career in the sciences.
Case Study: Kiley

Kiley is an undergraduate student in mathematics at the college. She is in her 9th year of college and has exhibited a discontinuous winding path. Recall that 4 out of 55 students reported having this path type. Of the 37 undergraduate students 1 reported a length of enrollment beyond 7 years.

Precollege

Kiley did not recall significant interactions with mathematics at a young age. She did, however, report that she knew that she had a natural ability to perform well in high school math courses. At the time this information did not persuade her towards a degree in the major. It is not until college that we really begin to see the formation of her mathematical identity. As this identity forms, it seems that other persistence factors, such as mentor presence, raised efficacy and others, begin to accumulate as well.

Kiley: Even though I thought I was better in math than I was in any of my other subjects, it wasn’t…it didn’t mean anything to me. Like growing up, I didn’t care about school the way I do now. I think that there were a few moments where I started realizing…so it was like, okay, I’m pretty good at [math] compared to like my friends, doing calculus in high school. I’m like okay, I get it a lot faster than you. But still it wasn’t something like “God, I got to be a math major.

College and Discontinuity

Kiley began her college experience at the institution of the study. She starts out in engineering, which required other math courses. She expresses a growing interest in the math courses but experiences a discontinuity shortly thereafter.
Kiley: So I think when I first started taking engineering courses um…here at [the institution], I was really bummed out when there wasn’t much math in it. Like it was calc calc calc, number crunching. I was kind of getting board of it and then um…I was really bummed out when I took my last math class that was required for the major. And so, I think it was [differential equations] that I took, I don’t remember if it was part of my major or not, but I remember just wanting to take more math classes for fun, and that’s what I did. I took [differential equations] […] that class was cool for me because like you know, you dealt with free fall, and you’re dealing with projectile motion, and so like engineering type-esque problems, that like I saw like why it was the way it was. You know I saw why velocity was the derivative of something. Like I saw why everything was happening and that really really intrigued me. I mean, but even after that I left school right.

Kiley: I didn’t start in mathematics. I started in engineering. Then I thought I might want to do math, so I took a couple classes. [Linear algebra] was something that made me feel like I just couldn’t do math. It’s that weird transition from calc, and this like proofy type of element that I wasn’t comfortable with, so I left school. I thought school wasn’t for me, so I left. I just worked and pursued a band at that time. And um…basically that’s what I was doing at that time. Looking for other things that I’m like good at. You know, even though school’s not for me, I was just like, looking for how I could still be successful without getting a degree.

At this time, a period of non-enrollment, Kiley searched for ways to be successful without obtaining a college degree.
A Return to College and Choosing Mathematics

Kiley decided to return to college. At this point she had been out of school for 4 years. It is upon her return that we get a real sense of Kiley’s mathematical development, interests, and the factors that contribute to her mathematical identity.

Kiley: So I came back and still, I was still interested in math like that class [differential equations] got me hooked. Like it kind of intrigued me. And so even when I left and came back, like taking stats I felt like a lot of people didn’t like it, but taking an applied course was cool for me because I was just like, was able to see more about how like math could be applied and how I could apply it. So I think that that was kind of like…well [differential equations] was an eye opener for me to see that yeah I really like this stuff, I think it’s cool.

Much of the interview data was richly centered about a specific statistics course taken upon Kiley’s reentry. It is in this course that she encounters an instructor who would emerge as a mentor, as well as students she considers influential in her path in mathematics.

Kiley: That class [statistics] was a big motivation […] I was always kind of like a B student Like an A-B student in math. And um…I feel like I never really understood it, like the way we understand it now, like looking back to [intro to set theory] I’m like “I didn’t know anything before”. And so I still didn’t at that time and so, I remember […] [the instructor] was interesting to me because […] I remember during the midterm I forgot the quadratic formula. I was like trying to figure out the quadratic formula after being out of school for like 4 years. I just couldn’t remember. After spending like a half an hour, I finished the whole test,
like quickly, and spent half an hour on this last problem, so I had to go up and ask him. So I went up and asked him and he was like so shocked that I didn’t know it. And I had told him really quickly like “I was out of school for this long” and he’s like…So he wrote it out for me and um…when I got the test back, long story short I ended up getting a hundred and that was my very first 100% on a test in math ever […] I was like whoa! I was like “I can do this”. Like being out of school for four years, I can do this. And that was very encouraging.

In the statistics class Kiley encounters a student who is nearing the end of his undergraduate coursework. This student seems to be an inspirational character in her journey to mathematics. Their interactions in studying for the course were meaningful and worthy of mention as part of Kiley’s story and formation of her mathematical identity.

**Kiley:** I remember one of the students that I was studying for the midterm with. He was like a huge influence. Like he was very successful student and um…in math, his name was [Carl] and I mean, he didn’t have to study with me because he was like, he knew everything. But he did and seeing how he thought, and he was already more advanced than I was. To see how he thought, I was like whoa, I don’t think about things the way he does. It was kind of like, inspiring, I want to think like that you know. He gets all of it like fully, to the ground level you know. And I wanted to get it like that. He kind of opened my eyes to see it like that and it was cool to see mathematics from a completely different perspective. Like not even being exposed to [introductory set theory] yet.
Discussing her reentry to college further, Kiley speaks more about the instructor and students in the statistics course. These individuals played different roles in her mathematical development. Over time she is acquiring mentors, productive peer groups, and momentum in her pursuits. She begins by talking about mentors.

Kiley: I think [the stats instructor] was one of them. For sure just my biggest influence and my biggest supporter […] I did research with him, I did [a scholarship] with him. And what led to the [scholarship program] was [Carl (from the stats course)], he had a friend that was in there [the program]. And um…so that kind of inspired me. I also met this guy named [Tim] in my stats class. So that [stats] class, like all the people that I met in there have like crazily influenced my math career after that. So this guy named [Tim], he was actually an econ major and a math minor but he was really into math, like he really enjoyed it…he was also in engineering and we became good friends […] He told me about [the scholarship program] and I talked to [the stats instructor] about it. Like it was kind of easy. I was like, “do you mind if we work on a project together if I were ever like to apply for [the scholarship]?” And he was like “yeah sure”. And I remember talking to [another instructor] about it later and she was like “wow, he took you as a student?… “you must be a really good students because”…she’s like “he’s really busy”. And I thought whoa…that made me feel really good. Another thing was, I had mentioned in the story before, that me getting my first hundred on the midterm, I think that was a really inspiring thing for me um…and it was because [the stats instructor] was nice enough to help me with the quadratic formula […] That incident was pretty big for me but um…it was like little by little, things were
happening. The [scholarship program] has to be another one of the biggest factors of a slow progression of how I like changed my life. Just seeing my academic path at a different level. Doing research. I didn’t even want to go to graduate school because doing research, like I don’t even know what that is, but it sounds terrible. I don’t know why it sounded terrible, but it did. Just that was my attitude. Learning about it and really understanding what it takes, and having supporters like [the stats instructor and others] by my side, I feel like “oh I can totally do this”. And then I realized, like I love it, research is just awesome and I finally get to really explore the ideas that I was interested in but didn’t have time to explore, or didn’t have enough, you know background, or something. I didn’t have a mentor. So I feel like that program was really a big influence to me.

Kiley continued to speak highly of the instructors and the students at the college. It is apparent that she felt and continues to feels supported by the community in which she is achieving her educational goals.

Since the statistics course Kiley has been on a continuous upward trajectory towards degree completion. She declared the major 6 years after enrolling in her 1st college course. She has since been awarded scholarships and provided multiple research opportunities. Each addition to her experience seems to build her confidence and love for mathematics. Kiley continues to engage in research, is on track to graduate and has plans of pursuing mathematics in graduate school.

**Summary and Connections**

Kiley entered a 4-year institution with the intent to pursue engineering coursework. Much like Cheryl, her efficacy was threatened which caused a discontinuity
in her college path. Whereas Cheryl’s efficacy was threatened in an engineering course, Kiley’s threat occurred in a mathematics course: “[Linear algebra] was something that made me feel like I just couldn’t do math. It’s that weird transition from calc, and this like proofy type of element that I wasn’t comfortable with, so I left school.” Kiley explored nonacademic options for 4 years and then returned to school. This was the main cause of her elongated path to degree completion. Kiley did spend time taking engineering courses and she is also receiving a minor in computer science. Though other definite causes of path elongation are present in the data, it is likely that her research commitments only allowed her to take so many units per term, whereas students with fewer commitments may be able to increase their course load.

Kiley’s mathematical identity is strong but is not something she acknowledged until taking college level mathematics courses. Kiley did not struggle in mathematics prior to college but also did not recall meaningful interactions until college. The development of a mathematical disposition is present when she begins to connect content from differential equations to concepts in engineering. She reported being “bummed out” when she leaned that she would cease taking math courses in the engineering major. Even so, she leaves college due to lack of or threat to efficacy in linear algebra, an idea that she extends to math in general. Kiley did not report engaging in any mathematics during her break from college. She instead pursued music. Upon her return to college Kiley encounters an emerging mentor and finds value in a community of students. She actively seeks opportunities to further involve herself. She is currently very involved in productive educational practices and has set goals for herself after graduation (e.g., graduate school).
In summary, Kiley had high math efficacy until her linear algebra class. Perhaps it could have been clearer that the course would involve the new “proofy” type of mathematical work. Perhaps having a prerequisite course in proof writing would have been beneficial. Kiley did not report mentors until her introduction of the statistics course. This class was also filled with individuals who were influential in her path. These were students who she seems to have modeled herself after. Envisioning herself within that community, and placing herself socially among those individuals, played a major role in her identification mathematically and her persistence in both research and continued education.

**Case Study: Thomas**

Thomas’s path is discontinuous and winding. He entered a 4-year institution directly, experienced a discontinuity, and later entered a community college before transferring to two different 4-year institutions. He is currently an undergraduate student in his 11th year of college (including discontinuities) and chose math in his 5th year. A discontinuous winding path was reported by 4 of the 55 survey respondents and none of the undergraduate survey respondents reported choosing math in year 5.

**Precoclelge**

Thomas reports to have always been good at math. He did not regard his talents as meaningful until approached by two concerned teachers in his 8th grade year. Prior to this he just thought that math was easy. Furthermore, he thought it was easy for everyone else too. After being approached by his teachers, regarding his ability, he better applies himself by attending to homework and helping other students; that is engaging in
productive practices. After which, Thomas maintained a steady pace in his mathematics coursework and excelled throughout high school.

**Thomas:** There was actually a turning point um... when I was in 8th grade. I took algebra 1 in 8th grade and I took pre-algebra in 7th grade. Both my 7th and 8th grade teachers sat me down during lunch period they called me into the room. I thought I was in so much trouble, like what did I do, what did I do? They sat me down and she had all of my 7th grade tests and then he had some of mine and I had perfects on everything. But I didn’t do the homework, I would goof off in class, so you know I wasn’t really attentive. I just thought it was really easy for me and I just thought it was the same for everybody else. So I thought everybody else was doing well so I didn’t really think I was standing out. [...] At first I thought, oh no they think I’m cheating. [...] They knew I knew my stuff because they started asking me questions about how would I solve this, how would I solve that, and I would answer it very easily. So they’re like “well he’s not cheating”. So they’re like, “why are you not putting effort towards this?” I’m like, “what are you talking about?” Little naïve 8th grader. They were chewing me out saying “you are so good at this, why don’t you just apply yourself” like “nobody else gets it like you do.” I was just sitting there like “uh...I don’t know, I guess...maybe”. And I never really had thought about it. Math was just...just easy to me. I never thought about it as something I wanted to be doing or put effort into it. School back then especially was not something that I was looking to put a whole bunch of effort into. You know, typical kid. So once they told me that and chewed me out it kinda scared me. That’s when I realized like okay, let me start doing the homework. Let
me start that. I was able to do the homework, like really easy. I was able to help out the other kids as well. And once I got into high school [it was a private school], you had to take a test and I scored in the top percentile and I took AP calc, I wanted to take AP stats but they wouldn’t let me take both. Those were the only classes that I really excelled in. All the other classes I kind of pushed to the side.

It seems that Thomas developed a productive disposition in mathematics after the interaction with his 7th and 8th grade teachers. Through high school his identity related to mathematics was much stronger than that of any other subject as he continued to pursue mathematics, taking advanced placement coursework, and even wanting to take two math classes at the same time. He claims to have had strong teachers through elementary school and high school and runs into his first opportunity for self-study in his AP calculus class.

Thomas: The first challenge I had was when I took AP calculus. Only because my teacher wasn’t really that good. So that was the first time I really had to self-teach myself. I always had really good math professors sine like elementary school and my first 3 years of high school. I always had teachers where they were able to explain it. And I just got it, it wasn’t hard for me. When I took AP calc, I don’t think my teacher understood the material himself. And he had a thick accent so it was really hard for me to understand what was going on at the time. So I had to self-teach calculus as a 17 year old. Now looking back, like, calculus is super easy but back then it was very challenging. I was able to self-teach and me and one of the other guys who, he was incredibly smart, we were the only ones who knew what was
going on in that class and we were trying to, or doing our best, to teach the other students how to do the material [...] I won an honors award for that class and it was really funny because you had all the AP students who had classes together and then me in their math class. I wasn’t known to be this really smart kid or anything but math was something that just came really easy to me. I don’t know why at that time it never occurred to me to pursue a career in that path. I don’t know why I chose economics but...I did. It would have saved me some time, I mean that was two years that I spent taking other classes.

**College**

Thomas enters a 4-year institution with intent to pursue economics. His story is different from the others, as we get a sense of the institutions’ role in some of the discontinuities. Further, Thomas is the first of the participants to experience multiple discontinuities. In order to clarify the many epochs of Thomas’s college career the interview data is separated into parts.

**Thomas:** I started college right after high school, I actually came here, in the fall of 2004, that was my first quarter. I was an economics major originally. I didn’t know what I wanted to do and I didn’t really look into college a whole lot, so I came here for 2 years, 04-06 as an economics major. I was gonna transfer to [an out-of-state university], two of my best friends went there, so that was all set, but then my financial aid didn’t go through.

**Thomas:** I also got in a really bad car accident so then I missed a whole year of school. When you miss 3 consecutive [terms] you have to reapply. At the time I started working at Best Buy so I was making decent money for...I think I was 20 at the
time. I had moved out so I was...I felt like I was on my own so I didn’t really push myself to go back to school so I missed a year of school and after I went to community college.

Thomas: I was so anti community college I felt like I was too good, like I couldn’t see myself there and it was really hard to push myself to go there and I did. [...] I switched to math and I went there for 2 years, I was finished in 2010. I think I got my associates.

Thomas: Then I transferred to [a 4-year institution] I moved out there and then I kept getting late registration. I did the orientation and everything I was supposed to but I kept getting late registration. I couldn’t take classes I needed to take so I don’t want to pay money, I was paying out-of-pocket at the time, I had money saved up to go back, and so I don’t want to pay out of pocket to take classes that I didn’t have to. So I missed one semester, and the next semester, same thing happens so I call up my counselor, I meet up with him, and I say “hey, why can’t I get any of the classes I need? I need a permission number or something” cause I just wasted a semester of not doing anything. I was already upset with myself for being way behind, and um...you know I had seen my friends graduate in like 08-09 and it was already like 2010 and I’m like barely getting myself back into university. It was putting me in a position where like I was uncomfortable and I didn’t like being in that position, I just want to be done with school already. I just missed that whole year by not going to school there.

Thomas: I had spent 6 years at Best Buy and I knew retail was not what I wanted to do for the rest of my life so I was like, let me push myself to go back to school. So I
reapplied here [...] they accepted me and I did my orientation. So I started here in the fall of 2012. [...] Since the fall of 2012 I was continuously enrolled.

Thomas was not encouraged to pursue mathematics initially, which caused his path to wind before choosing mathematics. He expressed a strong desire to complete his degree, however, in addition to external factors such as the car accident and having sufficient employment, there is a systemic element that played a role in impeding his academic path. First, his financial aid to transfer out of state did not go through. Then his car accident caused him to miss consecutive terms and required him to reapply to the college. Lastly, he was unable to get the classes he needed, due to issues of late registration. Though systemic restrictions were not reported by the other participants in the sample, issues of financial aid and late registration are common concerns among college students.

**Choosing Mathematics**

*Thomas:* The reason why I got into mathematics is because in high school that was the only AP class I took. It’s always something that I found easy. I was always able to grasp it. I liked economics in high school, in college I didn’t know what I wanted to do. I just picked economics because I liked that class. I enjoyed it but I don’t know what the heck I’m going to do with it but...you know. I was tutoring math a lot at the time and the parents would tell me like “you’re really good at this” and “have you ever thought about teaching?” and In my mind...In high school I was so anti teacher I would have never thought I would’ve wanted to become one myself. But then the more I thought about it, I’m like “why not?” It’s something I do enjoy, it’s something I’m good at. So then I started going that path.
It is clear that Thomas exhibited a productive disposition in mathematics.
Unfortunately, he was not guided in that direction during the transition to college. Instead he found himself, years later, still productive and enjoying mathematics as he tutored other in the subject. His interactions in this regard reinforce his mathematical ability and shift his mindset from anti-teacher to wanting to teach himself. This was the social aspect of Thomas’s choice to pursue mathematics. Below he describes his choice at the individual level.

**Thomas:** There were two things [...] With an economics degree, it’s like I wasn’t going to go anywhere unless I got a master’s or doctorate. So I thought, well maybe this isn’t the path I want to go down. Once I get the degree, what am I going to do with it? The other one was when I was tutoring, and everyone was telling me “you’re so good at this, why don’t you teach?” and then that’s what really pushed me to go into math. I mean I don’t know why I just didn’t start with that from the beginning. I think it was just me being stubborn. That’s what pushed me in my 5th year at community college to just do math, and ever since then that’s all I’ve done.

In the above account we are able to get a sense of Thomas’s thought process as he decides to change his academic path. He is seriously considering and weighing his options. He also recognizes his social interactions as indicators that he should pursue mathematics. Thomas’s statement “...I don’t know why I just didn’t start with [math] from the beginning...” is a powerful one and will be a topic for discussion in later sections.
Roadblocks and Mentors

Thomas was, at this point, headed towards completion of his degree. He spent much time trying to simply enroll in the classes he wanted in order to complete his degree. This endeavor has had its fair share of challenges. Here we account for a few substantial challenges as well as discuss significant mentors at the college.

Thomas: I’m actually the first person in my family to go to college. So that’s kind of a challenge because they don’t really know what it entails um...they kind of think well “oh you have a degree you should get a job”. Well no, that’s not how it works. There’s a lot of other things you have to consider. You know I’m trying to get internships and there’s a lot of extra-curricular activities that you should join. And they don’t really understand how it works, like how you set your own schedule. So they don’t really know. I mean my sister went to community college for I think 1 year but very, very brief. But none of them know what it’s like to be at a 4-year university. The thing is I’ve always had their support. [...] They support me, they just don’t understand what it entails. When I would come home stressed out, not being able to figure things out, they’re like “oh, why don’t you just tell your teacher that you need to take your test later”. Like it’s not like that, like high school or elementary where you could just tell your teacher “I’m gonna be sick” like no. You have to go whether you’re ready or not, you can’t just tell you professor like “oh, I don’t feel good” or “oh, I’m not ready. He’ll just be like “okay, don’t take the test and fail the class” you know? So that’s kind of been a challenge. I do have a tremendous amount of support from home. I had a lot of support from my dad and then I have a tremendous amount of support from my...
mom. Everybody’s always asking how I’m doing, and they know I’m graduation in June so they’re all excited.

It appears that like many of the participants, Thomas had emotional support from his family, however, they lacked the specific skills to support him fully. Being the first in his family to attend a 4-year university, Thomas’s family did not know how to properly guide him through the stresses that the college experience entails. Further they were likely unaware of resources on campus, which might have aided his struggles. This was challenging for Thomas. We provide one other account of challenges before giving information about Thomas’s mentors.

Thomas: I did have to withdraw last spring cause my father passed away [...] It was around midterms and I missed a lot of class and I wasn’t ready to take midterms. So that kinda pushed me back a little bit more because I would have been able to walk I think last year but I had to retake those classes, which are scattered. So this year I’ve just been trying to catch up on this class.

Thomas briefly mentions a teacher that did not suggest he withdraw from the course, but rather push through the challenge of missing class due to his father’s passing. As he stated, he had to wait another year to complete a class in which he had to withdraw. Mentors such as this teacher and others contributed to his mathematical identity even as he nears the end of his undergraduate career.

Thomas: I freakin love her to death. She really helped me when my father passed away. She allowed me to keep the class. I had missed so much time but she let me catch up and that allowed me to not fall way behind.
Thomas: I really liked [another instructor]. He taught me MATLAB and that was something that...I really didn’t think that I would be into that type of stuff. But talking to him...he was really, really helpful.

Thomas: These last few quarters I had [another instructor] for stats, and I talked to him a lot about actuary work. I was actually trying to pick his brain apart because he had worked...he does statistics. So when I started talking to him about grad school, that’s when...that’s what made me choose that path because he was a phenomenal instructor. I would go to his office hours and...You know, ask him a question or two, but then start asking him more about what path I should take. You know, what I could do with statistics. So he was really helpful about that.

This last account is really interesting. Thomas found his statistics instructor to be a “phenomenal” teacher. This teacher was influential in that it seems that talking with him more and more shifts Thomas towards an applied path in mathematics and a push into pursuing graduate school.

Still Winding

Though Thomas has converged to completing a degree in mathematics his path is still winding within the subject. It seems that just as he wanted to find the right major, he is now finding his focus within that major. He is finding that he wants to pursue statistics, which is interesting because he wanted to take statistics in high school, but was restricted from taking that class as he was already in an advanced placement calculus course.

Thomas: About 2 years ago I learned about actuary work, that really attracts...I went to a couple of seminars. I’ve talked to a couple of actuaries. So that’s the path that I really want to go down more...the statistical path. If I get into grad school here
then I’m looking to switch to statistics, because right now I’m a pure major because I wanted to teach at the college level.

**Summary and Connections**

Thomas’s path was elongated for many reasons. To start, he falls into the category of participants who were not encouraged or persuaded to follow a seemingly obvious academic path. Though Thomas performed well in and enjoyed mathematics, as demonstrated in his AP coursework and award, he did not pursue the major initially, rather his exploration began in community college. Nonacademic external factors also contributed to lengthening Thomas’s college path. He was in a car accident, which prevented him from attending college for a year. Also, the death of his father caused him to withdraw from coursework and retake a class the following year. Thomas stated that early on in his academic career it was difficult to push himself to continue school because he had employment and was hesitant to pursue classes at the community college. Lastly, upon enrollment to his second 4-year institution, it was a challenge to get the classes he needed to work towards degree completion in mathematics. Specifically, his inability to get the classes he needed prevented him from taking classes for yet another year.

Thomas was initially talented in mathematics but teacher involvement, helping others, and reinforcement from those he helped all played a role in the formation of his mathematical identity. Thomas always found mathematics to be easy but did not acknowledge his interactions as meaningful until 8th grade. This is when the two teachers “chewed him out” and told him that he should apply himself more. He was receptive to their words and did apply himself by participating in productive practices such as completing his homework and tutoring other students in the subject. His college career
begins in economics but he realizes, through the praises of others, that mathematics may be a more suitable option. Mentors, who he has developed connections with, play a role in his continued success and aspirations for further study. Nearly 11 years since his initial enrollment to a 4-year university, Thomas is finishing his degree in mathematics. His path is still winding in a sense in that he plans to pursue a different focus, statistics, if he is accepted to graduate school. Thomas’s mathematical identity is strong but still changing as he explores his future options.

**Interfacing the Case Study Data**

First let us remind ourselves that the interview participants share the experience of having attended college, continuously or not, for longer than 6 years. It was not explicitly stated in each case study, however, we must consider one universal trait. Each participant exhibited a winding path and did not enter college with the intent to pursue mathematics. Instead, these students found themselves in, or chose to pursue mathematics at a later point in their college career. This choice came at a cost. That cost was an elongated academic path. The participants had to give up units acquired in other subjects, often over the course of years, in order to complete a degree in mathematics.

The timing of the first meaningful interactions did not play a significant role within the sample. The interview participants expressed an interest in mathematics at different phases ranging from early childhood to college age. There was no demonstrated link between reports of first meaningful interactions and path length or type.

An interesting component of the participants’ mathematical identities was their will to acquire such an identity. What is meant by this is that there were more personal or individual factors than social factors which are present in the data in reference to each
participant’s identity. These factors might look different from case to case, however the presence of individual factors for identity and persistence can be found in each. Below are some examples of how these individuals played a role in their identities.

Javier’s rationale for continuing beyond college algebra was that he wanted to see how far he could go in mathematics. It is as if he was testing himself and his capabilities in each class. When he talks about challenging coursework, he states that he is a self-motivator and that being able to self-motivate is crucial to continue moving forward. Andrea self-navigates for a large portion of her path. She continued to take courses in mathematics though they were not needed. It was also not an advisor or mentor which convinced her to pursue mathematics, instead she takes it upon herself to research opportunities within the major. Mark considered that which he felt confident in (mathematics) and less confident in (Java, required for graphic design) and made the decision to follow that in which he perceived himself to have a “natural ability”. Also it is probably the case that he did not consult someone before sacrificing his living arrangements and food in order to finish college. It would be hard to believe that he was guided in that direction by a mentor, parent, or other influential people in his life. Kiley would have been supported had she not returned to college, however, after exploring non-academic options she decided it wouldn’t be enough. This was the case for Thomas as well. He experienced many setbacks and discontinuities but knew he wanted something better for himself than the future Best Buy could offer. He persistently re-enrolled in several colleges to get the classes he wanted and complete his degree.

In many of the case studies there is a sense of building mathematical identity in social contexts as well. Much of the sample expressed a desire to belong to specific
communities. Cheryl’s choice to pursue mathematics was solidified through a feeling of belonging to a community of educated individuals (new family members). Kiley, when situated within the statistics course, really began to build her mathematical identity through interactions with others. It is in this context that she discovers a faculty mentor and role models in a community that she wanted to be a part of. Recall that she stated about another student “I don’t think about things the way he does...I want to think like that.” Thomas also further develops a desire to pursue mathematics and teaching through social interactions. He tutored students, a position which reinforces his ability to explain mathematics to others. After multiple interactions such as this he embarks on a path to degree completion. Javier chose to pursue graduate study after his experience in the REU program. These programs generally model what continued research and graduate school might look like. Javier may have sought after the REU to situate himself in a community that was made appealing by that program.

It was common among interview participants to discuss family members. Two participants reported college educated family members. Cheryl’s parents were educators and her dad’s family consisted of academic individuals. She reports positive experiences attached to these two facts. First, that they had chalk boards at home to play school, which she enjoyed. Second, that identifying with her new-found family reinforced the decision to choose mathematics. Javier mentions his brother (who has his master’s degree) as someone who, in an indirect way, pushes him to go further in mathematics. Mark, Andrea, and Thomas reported that their families were supportive but there were also hindrances related to their lack of knowledge about higher education. Mark had to navigate financial aid details and procedures on his own, and Andrea reported feeling
“blind” as she was the first in her family to really pursue higher education. Thomas’s family was supportive but could not fully grasp the depth of his experience at the university level. Kiley reported that her mother was supportive in whatever it was she chose to do, be it mathematics or fast food. One commonality is that regardless of the level or role of family education, it seems that each participant did feel supported by their family in pursuing higher education.

Teacher involvement was a vital source for creating, supporting and maintaining the mathematical identities of the interview participants. Teachers engaged and involved the students in mathematics through a number of different ways. Such methods include presenting material in a way that meets the needs of all students, recognizing and encouraging developing talent and efficacy, being a source of both information and emotional support, and creating opportunities for co-curricular activities and involvement.

Though transfer status was not considered in selecting interview participants it does become relevant. Of the 6 participants, 5 transferred from a community college to a 4-year institution. Both Cheryl and Thomas began their college careers at a 4-year university but entered a community college after experiencing a discontinuity. Kiley was the only participant to begin and end her college career at the same 4-year institution.

Summary

Though the specific attributes of each case differs there are broader commonalities which exist among participants. Each participant’s path lasted longer than 6 years and was winding. Mathematics was not the first major of choice, nor were the students initially encouraged to pursue mathematics. Individual factors, rather than
societal factors, significantly contributed to the formation of mathematical identities and persistence within the mathematics major. Social context or positioning played a significant role in path type and the forming and maintaining mathematical identities for the individual. Teacher involvement also played a significant role in shaping or supporting the students’ mathematical identities. Family members are present and generally supportive in each story, yet are unable to help the students navigate the university system. Lastly, 5 out of 6 of the participants transferred to a 4-year university from a community college. Taken together, these commonalities point to institutional practices and societal issues that play a role in students’ elongated paths to mathematics degrees. These commonalities also raise questions about how our K-16 educational system might better serve these and other students. These questions are discussed along with recommendations in Chapter 6.
CHAPTER SIX

DISCUSSION

Conclusions

The goal of this study was to identify contributors to an elongated path to degree completion in mathematics, and further, to describe the formation of mathematical identities for students in elongated pathways. The findings suggest that there may be a lack of proper guidance for students as they transition to college, i.e., an inability to recognize student strengths and encourage academic pursuits in those strengths. This lack of guidance, or recognition, has been shown in the sample to have the ability to contribute to elongated pathways. Discontinuities further contribute to lengthier paths and were found in this study to be the result of threatened efficacy, systemic delays, and nonacademic external challenges. As for mathematical identities the sample was found to attach both social and individual experiences in data related to forming such identities. Positive interactions with teachers and peers played a significant role in the social context and had the ability to reinforce mathematical identities at different junctions of the students’ paths. The students themselves contributed to their math identities as they negotiated how they fit into the postsecondary structure. Each participant did not initially choose mathematics, instead came to the major over time. A universality of their experience is that these students were willing to make life-altering decisions and change their academic paths in order to pursue a major which suited them. They chose mathematics despite the cost of an elongated path.
Implications

Many of the interview participants were productive or performed well in mathematics while in high school but did not initially pursue the major in college. This begs the question of why? Why wasn’t their interest encouraged? What could have been done to bring these students to the major earlier? Perhaps precollege teachers could have marketed or promoted the major in more proficient ways. In Andrea’s case, she did not even know that mathematics was a college major. It is simply not enough that students pass math class, of importance is what they can do with that knowledge beyond the classroom. Teachers played a significant role in each participant’s path to degree completion and have the capacity to assist students in both the transition to college, and from college to the workforce or graduate studies. We are public servants entrusted with the task of fostering productive behaviors, and possibilities of a brighter future, for our students; the findings of this study indicate that one of the ways we may need to foster such behaviors and support students’ futures is through encouragement to pursue mathematics.

There was a correspondence between parent level of education and winding paths within the sample. Participants whose parents did not attend college reported being encouraged to pursue higher education, but lacked guidance upon or after enrollment. There are programs in place and efforts made to prepare students for the transition to college, but how can we prepare parents for this transition? Parents with limited knowledge for higher education should be familiar with financial aid procedures and costs associated with a college education. Those who qualify for grants, fee waivers and other forms of financial assistance should be informed about how to apply for such
support. Beyond financial issues one could be aware of details of stress and depression among students, common campus resources, and what is expected in terms of the enrollment (i.e., number of units) and hours of study (e.g., related to coursework). Not having access to this information, having never attended college, would certainly limit the ways in which parents can support/guide their children as they embark on their college education. Sure there is the internet, but parents need to know what to look for. The question remains then, how can we as educators, policy makers etc. create access to elements of higher education for parents as well as students?

Limitations

The interview sample is small but was chosen as such in order to attain a greater depth of data from each participant regarding their lived experiences. One might increase the interview sample size while narrowing the scope of the interview questions. This would allow the researcher to focus on a smaller set of central themes while reaching a larger population.

Interview data (small sample) did not reveal commonalities in regards to time of first meaningful interactions in mathematics. This theme was not addressed in the survey however it may be a worth investigating, since trends may appear in a larger data set. It might also be of value to explore transfer status in the survey. Though transfer status was not a determining factor for further participation, and thus not included in the survey, the small sample was comprised of a majority of transfer students.

Topics for Further Study

All but one of the interview participants were in higher level mathematics courses in high school; that is calculus, honors courses, and advanced placement courses. This
generates some questions. Why were these students not encouraged to pursue math? If they were encouraged, why were they not receptive to pursuing a mathematics major initially? There is currently a focus on the pipeline to college. In the STEM fields, wouldn’t these classes be a part of that pipeline? Perhaps these classes are emphasized as academic milestones that support college admission; perhaps there’s more to that story. In either case this issue is worth studying.

Through the student interviews we found that each participant exhibited a winding path. The question remains, is this telling of trends in a larger population of students in elongated paths? What of the students who enter college with the intent to pursue mathematics and take longer than 6 years to complete a degree? We did not get a sense of that story because the sample was universally winding.

Another unexpected outcome was the number of students who started their college paths in engineering. Half of the interview sample enrolled in college with the intent to pursue engineering. One might ask if this is true of a larger population of elongated students. Further, what can be said about students, not in elongated paths, who switch majors from engineering to mathematics?

**Closing Remarks**

One could say that there are negative associations or undertones when considering winding path students who take longer than 6 years to obtain a degree in mathematics; for instance, that a student in a winding elongated path is not serious about school, or academically wild, or impractical. Yet the data from this study indicates that these students are students who are trying to find the right fit. Having to change one’s course is not always easy but winding path students make these difficult choices in order to pursue
the right major. To be certain, the participants in this study swam against the current of attrition and found themselves belonging to mathematics, or rather it belonging to them. They persisted in higher education because it is the key to opportunity, success, and long-lasting career choices that suit their interests and identity. Thus, there is either a need for intervention when mathematical identities and dispositions are present, or a reason to further develop ways to increase access for all students during both their precollege and college years. There is also growing need to fill jobs in the STEM fields and a need to bring students to their corresponding majors quickly. With increased support in these regards, the hope is to increase STEM enrollment and foster mathematical ability, efficacy and creativity among students. These students might then complete degrees and transition more smoothly onto their future paths.
REFERENCES


Pierson Bishop, J. (2012). “She’s always been the smart one. I’ve always been the dumb one”: Identities in the mathematics classroom. *Journal for Research in Mathematics Education.* 43(1) 34-74


[http://www.eric.ed.gov/?id=529700](http://www.eric.ed.gov/?id=529700)
APPENDIX
COPY OF THE SURVEY

Student Consent

1. You are being invited to participate in a research study, which the Institutional Review Board (IRB) has reviewed and approved for conduct by Jennifer Gerry (Graduate student). This form is designed to provide you - as a human subject - with information about this study.

If you have any questions or complaints about the informed consent process of this research study or your rights as a subject, please contact the Compliance Office within Office of Research and Graduate Studies at The Institutional Review Board has reviewed and approved for conduct this research involving human subjects.

Purpose: The purpose of the study is to identify and describe the characteristics of a subset of students who follow non-traditional academic paths. The subset of interest is math majors who follow lengthier paths than the national average. Data from a larger population of math majors will be an excellent resource in describing the greater academic climate in which these students pursue a degree in mathematics.

Participation: You were selected as a participant because you are enrolled in a mathematics program at. If you agree to be in this study, you will be asked to complete a survey. In the survey you will respond to questions about your academic career. You may skip any question that you do not wish to answer. The survey should take approximately 20 minutes. There is no compensation for completing the survey. There are no direct risks or benefits for your participation.

Voluntary Nature of Participation: Your participation in this study is completely voluntary. Should you decide to discontinue participation, you may do so without penalty.

Confidentiality: All responses are anonymous. Your IP address will not be collected. Information, such as your name and e-mail address will only be collected if you choose to participate further in the study. Only the principal investigator, Jennifer Gerry, will have access to the survey responses. Analyses of the data may appear in publications or during professional presentations.

Questions: Should you have any questions please feel free to contact the principal investigator, Jennifer Gerry by e-mail

☐ I agree to participate and am at least 18+ years of age.
☐ I do not agree to participate.

Winding Roads to Success - Survey Study

Thank you for your participation, your input is highly valued. Please respond as accurately as possible to the following questions. The survey should take around 10-15 minutes to complete.
2. Which of the following applies to you?
   - I am an undergraduate student.
   - I am enrolled in a graduate program.

Major/Minor

If you are a graduate student, please respond to the questions on this page in regards your undergraduate career.

3. Are you a declared mathematics major?
   If you are a graduate student, was your bachelor's degree awarded in mathematics?
   - No
   - Yes

4. Which is (was) your program option?
   - Pure/secondary teaching
   - Applied/statistics
   - Not chosen yet

5. Will you be, or are you currently, working towards a minor?
   If you are a graduate student, did you receive a minor as an undergrad?
   - No
   - Yes. Please state the minor:

6. Will you be, or are you currently, working towards a double major?
   If you are a graduate student, did you double major as an undergrad?
   - No
   - Yes. Please state the second major:
7. How long have you been a student at ANY post-secondary institution? (length of time between your first college course, at any college, and the current point in your academic career)

8. How long after enrollment, in your first college course, did you choose mathematics as a major?

---

**Academic Path**

9. Which of the following best describes your academic path in college?
   - Continuous: Consistently enrolled as a part-time or full-time student since your first quarter/semester.
   - Discontinuous: Experiencing periods of both enrollment and non-enrollment in courses since your first quarter/semester.

10. Which of the following best describes your academic path in college?
    - Straightforward: You have consistently worked toward a specific program.
    - Winding: You have explored at least one other major (declared or not declared) before choosing your current program.

---

**Other Interests**

11. Have you, at any point, considered other majors? (Does not include double major, if applicable)
   - No
   - Yes, please list the majors considered.

12. Have you taken courses to explore the other majors considered? (Does not include double major, if applicable)
   - No
   - Yes, list the majors explored through coursework.

---

**High School**
13. Evaluate the following statements about your HIGH SCHOOL experience.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I was confident in my mathematical abilities.</td>
<td></td>
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<td></td>
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<tr>
<td>Mentorship was essential to my success.</td>
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<td></td>
</tr>
<tr>
<td>My electives were usually unrelated to the core curriculum.</td>
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</tr>
<tr>
<td>I was involved in many extracurricular activities (clubs, study groups, athletics, etc.).</td>
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<td></td>
</tr>
<tr>
<td>I was persistent when it came to working hard on my studies.</td>
<td></td>
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</tbody>
</table>

**College**

14. Evaluate the following statements about your COLLEGE experience.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I am confident in my mathematical abilities.</td>
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<tr>
<td>Having mentors has been essential to my success.</td>
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<tr>
<td>My electives are usually unrelated to my core coursework.</td>
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<tr>
<td>I am engaged in many extracurricular activities (clubs, study groups, athletics, etc.).</td>
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<td></td>
</tr>
<tr>
<td>I am persistent when it comes to working hard on my studies.</td>
<td></td>
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</tr>
</tbody>
</table>

**Course Perspectives**
15. Are there mathematical concepts in which you feel you have excelled?
   ☐ No
   ☐ Yes. Please list the subject areas.
      (calculus, complex analysis, number theory, etc.)
      
16. Are there mathematical concepts in which you feel less confident?
   ☐ No
   ☐ Yes. Please list the subject areas.
      (calculus, complex analysis, number theory, etc.)
      
Statement:

17. From your perspective, what is it like to be a student in a mathematics program? How do you view yourself among your peers? Are there factors which hinder your success, or perhaps are essential to it? Please address any or all of these questions.

Contact Information

18. This research will continue beyond the scope of this survey. If you would be open to further participation in the study, please leave some contact information. You may skip this step however further participation would be greatly appreciated.

   Name
   ______________________________

   Email Address
   ______________________________

   Phone Number
   ______________________________

Thank you for completing the survey, your contribution to this research is so greatly appreciated!