The Path to Math: Analysis of Student Mathematical Stories

Aurora D. Wallace

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THE PATH TO MATH: ANALYSIS OF STUDENT MATHEMATICAL STORIES

by
Aurora Wallace

A thesis submitted to the faculty of The University of Mississippi in partial fulfillment of the requirements of the Sally McDonnell Barksdale Honors College.

Oxford
May 2018

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I thank my friend Jessica, who sat next to me on the first day of Calculus I, for always being willing to talk math with me, whether it was working on homework or sharing math-related jokes.

I thank my interview participants from the University of Mississippi for sharing their stories about their triumphs and failures in math.

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Finally, I thank Ms. Melissa Graham of Eastern Washington University for asking me that life-changing question one day before class – “Have you ever considered majoring in math?” She was right.
ABSTRACT:

In this thesis, I address the issue of American students’ dislike of mathematics. I explored this issue in two parts: distributing a survey to undergraduates of the University of Mississippi and then conducting interviews of students at the same university about their past feelings and emotions about mathematics. Interview data was analyzed and coded through Dedoose, a qualitative data program. Analysis of each interviewee’s data set led to the establishment of different mathematical “paths” that students follow in their mathematics education. The five paths emerging from the data – Arrow, Improvement, Revelation, Sparkless, and Almost Revelation – provide a more individualized look at education and provide clues on how to help students change their minds and attitudes about mathematics.
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Section 1: The Problem

"I'm just not a math person."

“I hate math!”

"Why would anyone ever study that?"

Such are the typical responses mathematics majors receive after being asked the inevitable question in college, "What is your major?" Other students may not be so vocal in voicing their opinions of the subject, yet from their fearful, wide-eyed expressions, one can tell what they are thinking. Comments like the ones above point to a disturbing trend in views and attitudes about mathematics. For many in the United States, mathematics is a subject that inspires fear and even hate. However, there is hope for even the most fervent mathematics “hater” – I was one such student. After years of despising mathematics, I chose to major in the subject. My change of attitude inspired my interest in students’ mathematics feelings, which culminated in this thesis.

In this section, I will provide an overview of one of the major issues in mathematics education — students' negative attitudes about the subject. I will then define the purpose of this thesis as exploring reasons why students do and do not like mathematics. Finally, I will offer the following question: What do narratives about students’ mathematical experiences suggest for improving attitudes about the subject?
Defining the Problem

It is well-known that many in the United States do not like mathematics, whether they are adults finished with their schooling or elementary-aged children who still have many years with the subject ahead of them. A “Student Opinion” section of the New York Times titled “Are You Afraid of Math?” is one such example of the popularity of negative feelings with mathematics. Students of age thirteen and up were encouraged to comment on their feelings about mathematics. Many of the comments were negative, ranging from dislike, fear, and even hatred for the subject (Doyne, 2011). Even more troubling is the almost-triumphant attitude displayed by other people, who declare proudly, “I can’t do math.” Perhaps liking or disliking mathematics would not be such an issue if Americans were at least proficient in the subject. However, Americans cannot even boast of good mathematics scores. One indicator of this is the Programme for International Student Assessment (PISA), a worldwide evaluation of fifteen-year old students in the subjects of reading, science, and mathematics. Administered every three years, the most recent PISA was conducted in 2015. That year, United States’ mean score in mathematics was a 470, twenty points lower than the mathematics average of 490, and even further below the mathematics scores of other countries, such as the United Kingdom, China, and Canada (Organisation for Economic Co-operation and Development [OECD], 2016). Low mathematics scores coupled with American’s adverse reactions to mathematics is a troubling situation for mathematical education in the United States.

Adding to the problem is the fact that often a divide exists between the math-doers and the non-math-doers, whether intentional or not. The idea of innate
mathematical ability is widely believed and often even instilled in students (Guillaume & Kirtman, 2010; Harkness, D’Ambrosio, & Morrone, 2007; Latterell & Wilson, 2016). Those who have typically been successful in mathematics are not always aware of why those who hate mathematics feel the way they do. Likewise, the latter often see little reason to like the subject and do not understand why others love mathematics. This is a difficult chasm to cross.

Undoubtedly, mathematical education in the United States is in a crisis. Improving mathematical achievement is necessary, but how can educators even expect students to care about devoting more time, energy, and practice into a subject they so clearly despise? How can performance possibly improve if students are not interested?

The Purpose of the Study

Given the current state of mathematical education, it is crucial to find ways to help students overcome their dislike of mathematics and build a more optimistic relationship with the subject. By constructing a better mindset towards mathematics, it may be possible to improve students’ abilities in the subject as well. Why do students hate mathematics, and how can educators aid students in developing a better mindset?

The purpose of this thesis is to examine college students’ perceptions and attitudes about mathematics. Analyzing students’ past encounters with and feelings about the subject may suggest ways to improve both attitudes and performance. What events and influences caused students to enjoy or dislike the subject? Do any examples exist
where some individuals changed their mind about mathematics? By examining stories about others’ mathematical experiences, educators, regardless of their own personal feelings about mathematics, may be able to assist future students in developing a more positive attitude for the subject.

The Question

This thesis will investigate the following question: What do students’ mathematical experience narratives reveal about improving attitudes involving mathematics? The subsequent section provides a brief overview from current literature as to why students dislike mathematics, the usefulness of the mathematical biography as a research tool, and finally, findings from other studies involving the analysis of students’ mathematical stories.
Section 2: The Literature Review

For many students and adults in the United States, mathematics is a disliked subject. Animosity of the subject affects many in a variety of ways, ranging from the avoidance of applying basic mathematics in everyday life to uncomfortable physical symptoms. In some students’ cases, this aversion starts very young, even as early as elementary school, while for others, the distaste may develop in high school or college. No matter when individuals start disliking mathematics, the consequences can be alarming. Why is mathematics such a feared and even hated discipline, and how can educators combat these attitudes in their students? More specifically, what does analysis of student mathematical experiences reveal to improve attitudes about mathematics?

In this literature review, I will attempt to do the following: provide definitions of mathematics identity and mathematical self-concept; introduce the mathematical autobiography (or biography) as a research tool; and supply an overview of some reasons from literature as to why students may not enjoy mathematics. Finally, I will turn my attention to an interesting type of mathematics biography that Drake (2006) calls the “turning point story.” This special kind of story, which relates how individuals changed their attitudes about mathematics, suggests ways to help those with negative mathematical experiences learn to embrace the subject.
Defining Mathematical Identity and Mathematical Stories

One important definition in the discussion of mathematical stories, whether they are autobiographies or biographies, is mathematical identity. Bishop (2012) defines mathematical (or mathematics) identity as “to mean the ideas, often tacit, one has about who he or she is with respect to the subject of mathematics and its corresponding activities” (p. 39). She notes that mathematical identity encompasses an individual’s speech and actions, as well as others’ ideas about the individual regarding mathematics. For example, Bishop studied the relationship between two students to research mathematical identity in a small peer-group setting and discovered that the students’ interactions, including verbal communication, greatly influenced the mathematical identity the students chose to express. One student in Bishop’s study positioned herself as the mathematical “superior,” and through her actions and speech, helped label her partner as the “inferior” one at mathematics.

According to Kaasila, Hannula, & Laine (2012), mathematical identity is “something people use to justify, explain, and make sense of themselves in relation to mathematics and to other people acting in mathematical communities” (p. 979). They also stressed the difference of mathematics identity from the narrative version of mathematical identity. In contrast, other researchers stress the “story” aspect of mathematics identity in their definitions. Sfard and Prusak consider identities to be individual’s stories, both the ones they tell and the ones they listen to about themselves (2005). In that case, mathematical identity contains “stories related to how one interacts with mathematics both in and out of school” (McCulloch et al., 2013, p. 380). For the purpose of this thesis, I have adapted Bishop’s (2012) definition of mathematical
identities as being one’s ideas about one’s relationship with mathematics expressed through actions and stories. This definition stresses the concept of mathematical identity as ideas, unlike other definitions which consider mathematical identity to be collections of stories.

**Self-concept and self-efficacy.** Mathematical self-concept and self-efficacy are two other important definitions, because they also involve one’s relationship with mathematics, except on a narrower scale than mathematical identity. According to the OECD (2016), self-concept in mathematics can be defined as a “student’s beliefs in their own mathematics abilities,” while mathematical self-efficacy refers to “the extent to which students believe in their own ability to solve specific mathematics tasks” (p. 79). In other words, self-efficacy is “perception about task-specific competence” (Hauk, 2005, p. 38). Self-efficacy differs from self-concept because it is concerned with specific problems, not more generalized mathematical situations. Examples of both self-concept and self-efficacy often appear in mathematical stories.

**The mathematical autobiography.** The mathematical autobiography or biography is a common research and teaching tool used in mathematics education (Latterell & Wilson, 2016); it is helpful for understanding mathematical identities. McCulloch et al. (2013) defines a mathematical autobiography as “an individual’s retelling of her mathematics learning experiences using a written format” (p. 381), though other researchers have considered mathematical autobiographies in other formats, such as orally in an interview (Kaasila et al., 2012). Typically, a mathematical autobiography consists of “personally meaningful episodes, important persons, explanations, and the development of one’s beliefs of learning and teaching mathematics” (Kaasila, 2007a,
p.374). In other words, a mathematical autobiography is a story about the narrator’s lifelong relationship with mathematics as a student, teacher, or user of mathematics. Similarly, the biography form chronicles these same experiences of another individual. The term “story” is especially crucial, as Kaasila (2007a) defines a mathematical autobiography as a story of how a person creates their own mathematical identity, and some researchers even refer to them as “mathematics stories” (Guillaume & Kirtman, 2010).

Because mathematical autobiographies and biographies are stories, they typically have a plot (Kaasila, 2007a, 2007b), characters, and themes (Drake, Spillane, & Hufferd-Ackles, 2001). Plot is the narrator’s inner reasoning about the story’s events (Denzin, 1989, as cited by Kaasila, 2007b, p.206). Characters also appear in mathematical stories. Although mathematical identity primarily concerns the individual, teachers (Ellsworth & Buss, 2000; Guillaume & Kirtman, 2010; Harkness et al., 2007), family (Guillaume & Kirtman, 2010), and even classmates (Bishop, 2012) all help shape an individual’s mathematical identity and often appear in autobiographies or biographies. School environments are a common setting for many stories (Drake et al., 2001). As for themes, students’ feelings and experiences with mathematics are typically discussed. Clearly, both mathematical autobiographies and biographies are more than just episodes involving mathematics in an individual’s life; they are stories.

In summary, this section introduces several definitions crucial in analyzing mathematical stories. Since mathematical identity is primarily the ideas about one’s relationship with mathematics, it is present in all mathematical stories. When telling their story, individuals often discuss their mathematical identity either explicitly, such as
saying, “I am not a mathematics person.” or “I am good at math!”, or implicitly, by describing their feelings and experiences with mathematics. Self-concept often appears in mathematical stories as well, since it is connected to motivation in learning mathematics (Githua & Mwangi, 2003) and confidence (or lack of) in doing mathematical problems. Likewise, self-efficacy also occurs because people often name specific topics they either excel at or dislike in their stories, such as in Larkin and Jorgensen’s (2016) study. Because mathematical stories can provide detailed pictures of individuals’ relationships with mathematics, they are useful in determining various reasons why people enjoy or dislike the subject.

Why Do Students Dislike Mathematics? A Brief Overview

Mathematical stories, whether they are autobiographies or biographies, often consider both students’ triumphs and struggles with mathematics. It is impossible to list all the reasons why students may not like the subject. Contributing factors such as feelings, lack of understanding, and negative social influences are some of the common reasons explored in literature.

Anxiety about mathematics. Students’ mathematical anxiety is one common trend in mathematical stories. Mathematical anxiety can be defined as “feelings of tension, apprehension, and fear of situations involving mathematics” (Park, Ramirez, & Beilock, 2014, p. 103). Situations triggering mathematical anxiety occur not only the classroom, but also in daily tasks requiring mathematics (Ashcraft & Moore, 2009). Appearing in students of all grades, from elementary school (Larkin & Jorgensen, 2016)
to college (Henrich & Lee, 2011), it has been shown to cause low mathematical achievement (Park et al., 2014); however, moderate anxiety can be good for achievement when coupled with high motivation (Wang et al., 2015). Besides causing emotions, it also affects cognitive areas like the working memory (Ashcraft & Moore, 2009; Park et al., 2014), an essential tool in problem-solving (Hauk, 2005). Specifically, anxiety over mathematics tests is also common and affects performance undesirably (Ashcraft & Moore, 2009; Weinstein, Cubberly, & Richardson, 1982). As the result of anxiety, many students learn to avoid the subject as much as possible, whether by not signing up for more mathematics courses or in choosing a major that involves little to no mathematics (Ashcroft & Moore, 2009). Clearly, avoiding mathematics does not expose students to more mathematics, nor does it generally give them tools to overcome their anxiety. Anxious feelings towards mathematics then may linger, contributing to students’ dislike.

**Boredom and other emotions.** Negative emotions like boredom also appear in mathematical stories research. One of the major reasons why students quit mathematics is boredom, along with perceived dislike (Brown, Brown, & Bibby, 2008). Others argue that boredom is the result of students having a task that does not create any incentive for them (Pekrun, 2006). In other studies, being bored was considered a reaction to the teacher (Martinez-Sierra & García-González, 2017), or as a consequent of students’ difficulties with the subject (Larkin & Jorgensen, 2016). Whichever is the case, boredom is a common classroom emotion (Goldin, Yakov, Epstein, Schorr, & Warner, 2011), and some studies have discussed the importance of creating enjoyable, engaging activities to combat lack of interest (Villavicencio & Bernardo, 2013). Others have stressed the need to engage students in their own education, because students involved in class did not
describe themselves as uninterested (Andersson, Valero, & Meaney, 2015). Additionally, hopelessness and worry have been studied. For example, Tornare, Czajkowski, and Pons (2015) found that performance predicted hopeless feelings, and that when students believed they did well on a task, they were less likely to experience hopelessness. Larkin and Jorgensen (2016) reported that their video diary participants, 3rd and 6th grade students, conveyed their attitude about mathematics with words expressing hatred, boredom, or feeling upset. Therefore, boredom, hopelessness, and other negative emotions are frequently researched and may contribute to students’ dislike of mathematics.

**Misconceptions about Mathematics**

Another common thread in mathematical stories is that people often are confused as to what mathematics entails, why they should study it, or how it is useful to them in their everyday lives. Latterell and Wilson (2013) asked students from elementary school through college the following question: “What is mathematics?” All groups’ initial answers, even those from undergraduate mathematics majors, were ambiguous. In class, elementary school children reported they did “mathematics problems” while most non-mathematics majors responded that mathematics was either a “classroom subject” or “solving mathematical problems”, without any further explanation (p. 390). Elementary education majors thought mathematics was “just calculations,” and mathematics majors tended to view it as a list of “content” (p. 391). Larkin and Jorgensen’s (2016) study participants viewed mathematics as causing their negative emotions. At least two students mentioned their frustration at having to study it “all the time” (p. 935, 937) or questioned
the validity of studying mathematics. Interestingly, students in both studies typically viewed mathematics very differently than the authors, whether the authors considered mathematics a method for interacting and understanding the world (Larkin & Jorgensen, 2016) or as a process (Latterell & Wilson, 2013). While some differences in viewpoints between the two groups can be expected, the stark contrast is notable, causing Latterell and Wilson (2013) to comment: “One even wonders if those who like mathematics and those who do not are talking about the same thing. We argue that they probably are not” (p. 388). Furthermore, research has detected a divide between school mathematics and “real world” mathematics, where some students are unable to see the connection between topics and everyday problems involving mathematics (Boaler, 1999; Boaler, Kate, & Selling, 2017). Boaler et al. (2017) reported that none of their participants who had attended traditionally-taught mathematics classes felt school aided them with mathematics they encountered in their careers. Without understanding mathematics’ usefulness or the reason for studying the subject, some students may find it difficult to like mathematics.

Additionally, some people who do not like mathematics and are forced to participate for school or work reasons do not even consider themselves to be “mathematics doers.” Latterell and Wilson (2013) stated that students’ answers suggested that they thought some “other” group of people did mathematics. Picker and Berry (2000) also mentioned the “other” aspect in their analysis of students’ views of mathematicians. Through their drawings, students depicted the mathematician stereotype of the “white, middle-aged, balding or wild-haired man” (p. 89). In each country studied, students had the impression that mathematics was not a skill to be learned, but a natural talent of
almost mystical quality. Furthermore, this study suggests that gender and race play a role in students’ relationship with mathematics, which other studies confirm (Frenzel, Pekrun, & Goetz, 2007; Gilbert, 1996).

The “Turning Point Story”

Mathematical biographies and autobiographies are enlightening for research, but to change students’ minds about mathematics, a specific type of mathematical story, which Drake (2006) refers to as “turning point stories” (p. 579), is particularly useful. A turning point is an event “in which the protagonist gains new insight” (McAdams, Diamond, de St. Aubin, & Mansfield, 1997, p. 680), where the protagonist is the narrator or the individual whose story is being told. Both positive turning point stories and negative ones exist (McCulloch et al., 2013). Also identified as “areas of transition” or “changes in attitude” by Ellsworth and Buss (2000), positive turning point stories are told by students, teachers, or other individuals whose intense dislike of mathematics turned into appreciation or even enjoyment of the subject. McCulloch et al. (2013) defines a “positive turning point learner” as “characterized by strong negative memories of mathematics up until a particular point (a turning point) in which one specific positive experience results in a more positive attitude towards mathematics” (p. 387). These stories differ from other types of mathematical stories such as the so-called “roller coaster” mathematical stories, because turning point stories seem to demonstrate a more permanent change in an individual’s relationship with mathematics (Drake et al., 2001; McCulloch et al., 2013). Evidence of turning point stories appear in various studies, especially ones involving analysis of mathematical autobiographies or biographies.
The role of the teacher. The impact of a teacher is one of the major themes appearing in turning point stories. Literature has suggested the importance of the teacher’s role in both students’ dislike and like of math. Gilbert (1996) found that liking their mathematics teacher was the second most frequently chosen reason for why students picked mathematics as their favorite subject, behind their perceived mathematical ability. Similarly, students often mentioned teachers when discussing their dislike of mathematics or struggle with the subject. Larkin and Jorgensen (2016) reported that some participants mentioned mathematics teachers yelling during class and claimed this added to their dislike. Correspondingly, Guillaume and Kirtman (2010) found some prospective teachers remembered mathematics instructors who made them feel unintelligent, insulted them with words such as “stupid” (p. 136), or had no belief in their mathematical abilities. For the positive turning point stories, teachers were often responsible for an improvement in the student’s attitude towards mathematics (Ellsworth & Buss, 2000; Guillaume & Kirtman, 2010; Harkness et al., 2007). Many turning point story participants mentioned teachers who believed in their students and helped them discover that they could succeed in mathematics (Guillaume & Kirtman, 2010). Harkness et al. (2007) also reported their turning point story participants mentioned specific teachers when talking about their changes in their mathematical ability. Likewise, the participants attributed their success to these particular teachers. In addition, McCulloch et al. (2013) credited teachers; change happened because of a teacher who cared or placed high expectations on them. Teachers causing a turning point for students is not surprising, given that these professionals are known to have a significant impact on their students.
**Acting as a teacher.** Another interesting theme appearing in some positive turning point stories is the presence of teaching or tutoring math. Studies have suggested that helping others learn mathematics can cause one to change one’s own attitude about mathematics (Drake, 2006; Ellsworth & Buss, 2000; Henrich & Lee, 2011; McCulloch et al., 2013). In a quantitative reasoning course at Seattle University, Henrich and Lee (2011) found many humanities majors with mathematical anxiety who developed a more positive attitude towards mathematics after the department added a service-learning component. These students were required to tutor elementary or middle school mathematics locally, and in their essays, group interviews, and final passing grades, they suggested that the experience helped transform their attitudes about mathematics. Several students stressed the importance of displaying a positive attitude for the children. They described how originally forcing an upbeat attitude during tutoring, actually altered their own feelings about mathematics in a positive way. Furthermore, Leila, one of the mathematical biography participants in Kaasila’s (2007) analysis, also claimed her turning point occurred as a preservice teacher, when she decided to focus lessons centered on the student (Kaasila, 2007b). In Drake’s (2006) study of teachers’ narratives, four of the six teacher participants experienced their changes in mathematical attitude during their teaching careers rather than as a student. Therefore, teaching or tutoring mathematics seems to be a turning point in some individuals’ stories.

**The mode of learning.** Making students more active in their learning is another common thread. Mastery goals combined with a social constructivist classroom reportedly helped some students develop a more positive mathematical attitude in Harkness et al.’s (2007) study. Interestingly, their data confirmed Ames and Archer’s
(1988) idea that mastery goals, a motivation of “learning for learning’s sake” (p. 235), did help some students overcome their idea that they are not capable of doing mathematics. Harkness et al. also found that with mastery goals, students will extend more effort towards somewhat challenging problems. At the end of the study, one student felt confident in his or her skills to solve mathematics problems, even though mathematics was still difficult. As a result of this finding, Harkness et al. recommended promoting mastery goals more heavily for students who dislike mathematics and believe that they cannot change their mathematical abilities through effort. Simply changing the way the material was presented was another method used to make students who detested mathematics more involved (Andersson et al., 2015). Andersson et al. observed that when they introduced mathematical concepts with a focus on issues of interest to the students, the class was more participative and willing to describe themselves as such. Thus, being active in learning appears in several turning point or positive mathematical stories.

A change of view. A change in viewing the material, or mathematics in general, is another common theme of positive turning point stories. Too often, mathematics class is taught using the drill method (Gilbert, 1996; McCulloch et al., 2013; Zimmerman, 2002), which may not be the ideal way of learning mathematics for some students. In the literature, presenting the material differently took the form of new curriculum elements like manipulatives (Drake, 2006), learning with more focus on “real world” applications (Ellsworth & Buss, 2000), or simply realizing that there are often multiple ways of solving a problem (Drake et al., 2001). Claiming the use of manipulatives as her turning point, one teacher described them as an entertaining or, novel method for teaching mathematics. Another instructor made the following interesting comment:
“I think I never thought of mathematics as like— I think I always looked at it as right or wrong and not, ‘Oh, this way or that way’, or, ‘You did it this way—wow’, or whatever. I never looked at it as having more than one way to get there.”

(p. 9)

For this participant, simply the idea that mathematics problems can be solved in multiple ways was enough to help change her perspective. This revelation appears in other studies as well. Boaler et al. (2017) reported that in their study of two schools with different mathematics curriculum, former students in the more creative program enjoyed mathematics and praised the open structure of the program. Similarly, Anderson et al. (2015) noted that negative mathematical identities is related to learning situations. One of their participants shifted between someone who hated to someone who enjoyed her mathematics class, depending on how the lesson was taught. The student professed to despise mathematics when taught in a traditional way, but when other elements – such as class discourse and students’ interests – were added, claimed mathematics could be enjoyable. Therefore, changing students’ views of the material seems to be another way to change minds about mathematics.

Turning point, or similar positive mathematical stories, are useful because they provide clues as to how to help students improve their attitudes about mathematics and like the subject. With the job market increasing in STEM-related jobs, as well as the fact that poor attitude and skills in mathematics drive students away from STEM fields (Ramirez, Gunderson, Levine, & Beilock, 2013), it is crucial for educators to find a way to help students appreciate and perform well in mathematics. How engaged a student will be with mathematics is often indicated by their emotions regarding the subject (Bishop,
In particular, enjoyment also has been shown to positively affect performance (Schukajlow & Rakoczy, 2016). Enjoyment of mathematics may not immediately cause results, but in the long-term, can be a deciding factor on whether a student continues mathematics classes (Pinxten, Marsh, De Fraine, Van Den Noortgate, & Van Damme, 2014). For those with turning point stories, some credited their change in attitude to strategies used by their teachers that made mathematics more pleasant. Additionally, Brown, Brown, and Bibby’s (2008) data concluded that using enjoyment and excitement to decrease boredom may be the best way to increase mathematics participation rate.

Enjoyment of mathematics looks to be a promising option for helping students foster a more positive mathematical identity.

Research is too focused on students’ mathematical performance—the problem itself—or on improving students’ achievement levels in mathematics. It does not adequately address how to help students like mathematics in order to change their attitudes; the current focus is on competence, not enjoyment. When participating in a study of literacy identities, teachers discussed how reading was a personal and rewarding experience for them, yet there was no such fondness for mathematics (Drake et al., 2001). By valuing competence over enjoyment, how can educators expect students to think beyond the idea of mathematics just as a classroom subject? How can educators convince them that it is a worthwhile pursuit and an enjoyable activity, not just a class to be endured and promptly dropped when no longer mandatory? Turning point stories, which feature students learning to like mathematics, are not extensively studied (McCulloch et al., 2013). One possible reason is that such stories may even be few or difficult to find, given that the turning point often occurred because of circumstances
outside of the experiencer’s control. Perhaps now it is crucial to consider the importance of enjoyment and other positive experiences in helping students change their minds about mathematics.

How can this actually be accomplished? Do mathematical biographies contain any clues on how to change students’ feelings about mathematics? These questions inspired the following research collected through University of Mississippi undergraduate students’ surveys and interviews on how to help people enjoy mathematics to foster positive mathematical identities.
Section 3: Research Methodology

This study consisted of two parts – an online survey and individual interviews. The focus of the survey was to gather preliminary data from a group of students and determine their overall thoughts and feelings about mathematics, while the interviews focused in-depth on six individuals’ stories and experiences with the subject. I will discuss basic information about the participants in this section and briefly describe the setting and data collection for the study.

Participants

The participants of this study were currently enrolled students at the University of Mississippi. All participants were currently undergraduate students, except one participant, who was studying for a graduate degree but had completed her undergraduate degree at the university. Survey participants included twenty-nine students from mathematics education and lower-division mathematics courses. Interview participants were primarily mathematics education and/or mathematics students, all of whom were female. Pseudonyms were assigned to each participant. See below (Table 1) for interview participants’ information:
Table 1
Participant Information

<table>
<thead>
<tr>
<th>Participant</th>
<th>Major:</th>
<th>Classification:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – “Emily”</td>
<td>Education</td>
<td>Graduated (current graduate student in Education)</td>
</tr>
<tr>
<td>2 – “Amy”</td>
<td>Mathematics</td>
<td>Senior</td>
</tr>
<tr>
<td>3 – “Madison”</td>
<td>Mathematics</td>
<td>Senior</td>
</tr>
<tr>
<td>4 – “Megan”</td>
<td>General Studies (Mathematics Education Minor)</td>
<td>Senior</td>
</tr>
<tr>
<td>5 – “Nicole”</td>
<td>Mathematics</td>
<td>Senior</td>
</tr>
<tr>
<td>6 – “Hayley”</td>
<td>Communication Sciences and Disorders</td>
<td>Senior</td>
</tr>
</tbody>
</table>

Setting

All research for this thesis was completed at the University of Mississippi, a public university located in rural Oxford, Mississippi. This setting was chosen because I, the investigator, am a student of the university and am interested in how my peers at the institution regard mathematics.

Data Generation:

This study was broken into two major sections: survey and interview. Firstly, a ten-question survey (see Appendix A) was forwarded to students enrolled in sections of mathematics education (mathematics for elementary school, secondary education classes, etc.) and lower-division mathematics courses (precalculus and calculus sequence). The survey was completed digitally with Qualtrics survey software. At the end of the survey, participants were asked to indicate whether they wished to be contacted for a more in-depth interview. Two of the interview participants were recruited in this manner; the remaining six who originally indicated interest did not respond to the emailed interview
request. The other four interview participants were a convenience sample (known by the author and/or the advisor) invited in-person to participate in the study.

Interviews were conducted either at a quiet, off-campus coffee shop or via FaceTime at the interviewees’ request. Questions were asked off a 10-prompt interview script, but the participants were free to discuss whatever they wished regarding mathematics. Prompt questions included favorite and least favorite mathematics memories, favorite teachers, examples of when they found mathematics difficult, and other questions regarding emotions and experiences with the subject (See Appendix B). Interviews took approximately 20-45 minutes, and data was collected through interviewer notes. Following the interview, details remembered were written down and added to the initial notes. This was done immediately after the interview to ensure all data recorded was correct and as complete as possible. Details included memorable phrases, words, and emotions the participant used during the interview that were not recorded in the notes taken during the interview. All names, places, and other identifiers were removed from the data to protect privacy; all interviewees were referred to by the word “participant” followed by a number (as in Table 1) in data analysis and in the following sections of this thesis.

Data Analysis

Handwritten interview notes were typed in a word processor and then uploaded into Dedoose, a qualitative and mixed method research application. Several rounds, or “cycles” (Saldana, 2013), of coding were applied to the data. The purpose of the first
round of coding was to become familiar with the data and identify instances of interest that emerged in the initial reading (Richards, 2009). The second round of coding marked all data from the interview notes, excluding the details filled in after the interview. Subsequent rounds of coding involved identifying places where the student experienced positive and negative emotions, content areas and learning practices the participant discussed, and the role of teachers in participants’ memories. Findings were developed by examining code co-occurrences, noting commonalities within prior rounds of coding, and creating diagrams that represented different student “paths” in mathematics. Survey data was exported from Qualtrics and compared to interview data after the latter had been coded in order. This was done to help verify the conclusions made from the interview data. In the next section, I will describe the findings generated by analyzing the data.
Section 4: The Findings

During data analysis, several different “paths” participants took during their mathematics education emerged from the data. I define “path” as the emotional relationship a student has with mathematics as they advance through the subject with respect to time. In this section, I will introduce each of the paths revealed. The first path is *Arrow*, in which a student is stable in his or her feelings about mathematics. The second path is *Improvement*, which describes students who always have liked mathematics, and after a certain experience, become passionate about the subject. *Revelation*, which refers to a student’s dramatic shift in attitude towards mathematics, is the third path. The last paths from the data are *Sparkless*, representing students who never have an experience with mathematics that causes them any lasting change in attitude, and *Almost Revelation*, which is a combination of *Revelation* and *Sparkless*. First, I will define the term “spark” in terms of paths and show its importance in fostering positive feelings about mathematics in students.

**Defining “Spark”**

Spark (n.): something that sets off a sudden force (Merriam-Webster, n.d.)
In four of the six interview participants’ data, there existed a certain experience or set of experiences that caused a significant shift in the student’s attitude about mathematics. In the cases of these mathematics students, these experiences generate a fateful “spark” that led to genuine interest in mathematics or enjoyment. In the case of the mathematics majors, many claimed these experiences drove them to study the subject.

As stated in Section 3, Amy, Madison, and Nicole were the mathematic majors in the interview data set. Each of these students discussed her spark during her interview. For Amy, her spark involved mentor figures. She formed a close bond with her freshman advanced algebra teacher, who she claims became “a life mentor” to her during her remaining high school and early college years. While Amy explained that she was always good at mathematics in school, she credits this teacher for igniting her love for the subject. This teacher helped her with mathematics and advice on other life issues. She remembers coming to her mathematics classes with this teacher early, and her love for mathematics blossomed that year. Amy then continued her mathematics education the following years with AP courses and other advanced mathematics opportunities. In her freshman year of college, she initially chose another program, but her advisor praised her mathematics grades and suggested that she major in the subject. The combination of her mentor and advisor created a spark that led her to continue her mathematics studies.

Nicole’s spark also occurred in high school, but it involved a specific class. She claimed that mathematics was always easy for her until her high school trigonometry class, in which she was forced to study. For the first time, she felt “challenged” and considered pursuing a math-related career. Madison’s spark occurred much later than the other interviewed mathematics majors. In college, she took mathematics classes for
another major, but during her calculus sequence classes, decided she really liked mathematics and would “miss it” when she had no more required mathematics classes left. When she decided to switch her major, she decided on mathematics because of her newfound love for the subject developed in her community college years.

Emily, though not a mathematics major, also had a “spark” in her college years. After spending most of her prior education greatly disliking mathematics and not understanding it, Emily was assigned to 5th grade mathematics for the student teaching section of her undergraduate program. Her experiences in her student teaching led her to develop a new, positive attitude towards math, and she later taught 5th grade mathematics as a full-fledged teacher.

Therefore, the interview participants’ sparks occurred as either combinations of teachers, mentors, and experiences where they felt challenged or motivated to study the subject. However, Megan’s and Hayley’s stories did not feature sparks. Their stories’ lack of sparks will be discussed later in this section.

**Student Paths**

The following subsections describe the five student paths that emerged from data analysis.

**Path One: Arrow.** The first path observed from the data is the Arrow, represented by Nicole. This path’s name is derived from its straight, rigid nature. A student who follows an Arrow path has mostly stable feelings about mathematics throughout his or her
education. Arrow paths can encompass positive, negative, or neutral feelings, but not a combination.

Nicole had a very straightforward path throughout her mathematics education. Always someone who enjoyed mathematics, she described herself to be “more of a math/science person instead of a subjective fields person.” Despite various obstacles, she continued to have positive feelings about the subject. As mentioned above, her first interest in a mathematics career occurred in her high school trigonometry class, which she claimed was the first mathematics class for which she studied. While some students may have felt differently, Nicole rose to the challenge and stated that it increased her interest in mathematics. Later in her high school years, she took a calculus course with a teacher who she said did not teach. Even when she was faced with a frustrating situation that could have caused her to resent or despise the subject, she continued to love math. Rather than rely on the teacher, she and her classmates used YouTube tutorials and other reference materials to teach each other. Nicole majored in mathematics, and while she encountered other difficult situations, she continued to enjoy and stay motivated in studying mathematics. One trouble spot of her undergraduate studies was learning to write proofs. She stated this class caused her some anxiety, especially with tests, because she felt unprepared. However, she had no lasting mathematical anxiety once she finished the course and later took many more proof-based courses for her degree. Nicole’s story suggests that while specific circumstances, such as teachers, classes, etc., can cause an Arrow student to feel differently about mathematics, they have no lasting change on the student’s overall feelings about the subject.
Path Two: Improvement. The second path observed was Improvement; Amy (Participant 2) followed this path. Starting at neutral or slightly positive feelings, Improvement students experience circumstances (a spark), and their attitudes change to enthusiasm about mathematics. Improvement differs from Arrow because it exemplifies a change in attitude, whereas students with an Arrow path have unchanging, long-term feelings about math.

Amy claimed she was “always good at mathematics generally, maybe not a ‘genius’,” but starting in middle school, was able to learn the subject without much difficulty. However, prior to high school and college, Amy “never loved math.” In retrospect, however, she considered mathematics to be her favorite school subject. Although Amy did not discuss her mathematics experiences prior to middle school, given her above statements, it is reasonable to assume her feelings about mathematics were not negative during that period of schooling. While Amy did not dislike math, she was not enjoying it either.

As mentioned above in the “Defining Spark” section, Amy did not enjoy mathematics until high school, where she had teachers who encouraged her curiosity and ability. Her mentor freshman algebra teacher provided a spark, and Amy pursued her mathematics interests. She took AP mathematics classes, such as statistics. However, she explained that she hated statistics in high school because she did not understand it. She also was forced to work problems on the board, which made her feel uncomfortable. Despite this experience, she continued taking advanced mathematics courses and enrolled in classes taught by professors from a nearby university. She claimed this allowed her to experience college mathematics courses while still in high school. Trigonometry was her
favorite, as she enjoyed memorizing the Unit Circle. In high school, Amy’s full potential and ability to enjoy the subject was sparked.

Another difficult experience occurred for Amy after she began her college mathematics program. She remembers her first proof-writing course to be demanding, as she said it was “so abstract” compared to her previous mathematics classes. Prior to her proof-writing course, she had not seen proofs and so “words and math” together was a puzzling, frustrating experience for her. She tried memorizing proofs like she had memorized mathematics formulas, but it did not work well for her. Despite the sudden difficulty, she attended office hours and began learning how to write proofs. She passed the course and successfully took more proof-based mathematics classes for her degree. While at the time of the interview she still did not enjoy proofs, Amy emphasized her love for mathematics and wished she had become a mathematics major sooner, rather than starting college in another major.

Amy’s mathematics story was interesting because of her change in attitude about mathematics. While she never disliked mathematics, she did not enjoy it until she encountered her freshman high school algebra teacher. After undergoing this change, future mathematical difficulties and obstacles did not deter her, nor did they affect her love for the subject.

**Path Three: Revelation.** Perhaps of all the paths appearing in the interview data, Revelation was the most interesting, as it featured the most dramatic shift in attitude. The study had two examples — Emily and Madison — of this path. Revelation is
characterized by a starting negative or neutral attitude about mathematics, which then develops into more negative feelings until a spark occurs. Then, the student begins a transition upwards from negative to positive to very positive feelings about mathematics. Afterwards, students with Revelation paths maintain their very positive mathematical attitudes. In both Revelation paths of this study, the students came to love mathematics so much they pursued a math-based career.

Emily (Participant 1) was the first example of the Revelation path. Placed in the gifted program at her school, Emily experienced frustration from an early age with mathematics because of her reputation as a “gifted student.” She had difficulty memorizing multiplication tables in third grade and struggled to understand other mathematical concepts, but she felt her teachers did not take her mathematics hardships seriously – they believed that she simply was not trying. Emily claimed she then “shut down” in her mathematics classes. She struggled with in-class homework but did well on the exams and had no test anxiety. According to Emily, her successes on the exams frustrated her teachers, causing them to believe that she was lazy. Emily’s motto with mathematics classes became “Enough to get by.” Ashamed of her mathematics difficulties despite being a very good student in her other classes, she decided she was not a mathematics or science person at all.

One brighter spot in Emily’s mathematics education occurred in high school. Her physics teacher, a standup comedian, realized her struggle and decided to work with her until she understood the concepts. He used many examples, such as one about texting and driving. Emily claimed his lessons were more relatable and meaningful than previous teachers’.
Emily’s spark that led to her passion for mathematics occurred in college. The first time she felt she clearly understood mathematics and how to teach it was in one of her mathematics education courses, where she used manipulatives and other nontraditional ways to learn. In her senior year, Emily was placed in 5th grade mathematics for the student teaching component of her education program. She admitted to crying when she found out her assignment, because it was mathematics and she did not want to teach that subject. However, after the initial shock, Emily resolved herself to the idea. She decided that although she felt uncomfortable with the idea of teaching mathematics, she was going apply herself and “get through it,” because she wanted to be a teacher. Emily prepared by studying the material. When she started her student teaching, she realized that many of the students she encountered had the same difficulties that she did. Emily found it rewarding to “see the lightbulbs go off” when her students finally understood a concept; she found she liked being for her students what she wished her teachers had been for her. Slowly, her newfound acceptance turned into liking and then finally enjoyment of the subject, to her mother’s surprise. “I don’t know what you did, but I spent money on tutors for her all those years,” she told one of Emily’s professors. After graduation, Emily taught 5th grade mathematics as a full-fledged teacher, and she then returned to the school for a graduate degree, completely changed in her attitude about mathematics.

Madison is the other example of the Revelation path in the data. She was homeschooled for most of her education, except for a couple of grades in elementary school. Unlike science, which she liked and was good at, mathematics did not make much of an impression on Madison. Her early memories of mathematics were negative
ones. She was not quick with mathematics computations, and her mother graded her homework problems strictly. During her time not homeschooled, she also disliked math. She recalled doing timed multiplication tables and remembered hating them. In late middle school, she practiced mathematics over the summer with a tutor.

Like Emily, Madison’s change of heart about mathematics occurred in college. However, when she began college, the idea of taking mathematics classes was “terrifying,” as “everyone” had told her that “mathematics is hard.” After considering some other majors, she decided on business and nervously signed up for the first business calculus course. After being successful in that course, Madison took regular Calculus I and II. She also did well in those courses; she remembers earning the highest grade on the last Calculus I exam in the class, which was a major boost in her mathematical confidence. Calculus III she claimed was the mathematics class she really enjoyed, as she liked the professor’s in-class persona. She remembers him being funny but also explaining things well. Additionally, she liked the content of Calculus III – sequences and series. While Madison stated she typically makes many little, “dumb mistakes” in math, she enjoyed yes-or-no questions such as determining whether a series converged or not. Madison then took other mathematics courses, such as Calculus IV. Therefore, Madison’s spark to keep pursing mathematics was her experiences in the calculus sequence, particularly those in Calculus III.

At this point in her college career, Madison decided to change her major. She was not sure what she wanted to major in; she just knew that she would miss doing math, as she really liked the subject now. Her lab partner knew a mathematics major and talked to her about switching. Madison liked the idea, but she had heard that mathematics became
very theoretical and centered on proof-writing, something she had no experience in. However, Madison finally decided to major in mathematics and was successful in the program.

Emily and Madison’s mathematics stories were similar in the fact that they featured a student who began her mathematics education with neutral feelings and grew to hate the subject until college, where they experienced a spark that changed their minds and convinced them to continue the subject. Both Emily’s and Madison’s sparks featured teachers and experiences that forced them to engage with mathematics. Emily was required to student-teach math, and Madison’s major at the time, business, mandated that she take mathematics courses. While both were exposed to math, albeit somewhat unwillingly, these circumstances allowed them to experience success, maybe for the first time, with mathematics.

**Path Four: Sparkless.** This path was characterized by lacking a spark. Students with a Sparkless path have neutral, slightly positive, or negative feelings about mathematics. More extreme emotions such as love or hate do not appear in this path. Sparkless differs from Arrow because it allows some variation in feelings; however, there are no experiences that spur the student to more extreme emotions about mathematics. Like Megan (Participant 4), who claimed “nothing major” stood out in her memories of mathematical education, students following a Sparkless path have no major circumstances that force them to more fully engage and love the subject. Megan said several times in her interview that she liked math, but her story lacked the passion for the subject that other participants shared.
Megan represents the Sparkless path. Interestingly, Amy (Improvement path) and Megan began their mathematics education journeys similarly, but their paths diverged in high school. Megan claimed she always “liked mathematics and understood it well.” She did mention not enjoying the many timed exercises she did in elementary school, one being 60 seconds to complete a page of problems. However, during elementary, mathematics was her favorite subject “for sure.” Her favorite mathematics teacher was her 4th, 5th, and 6th grade teacher, who Megan said she liked because the teacher was “familiar.” In high school, Megan chose to take non-AP classes and continued to maintain a positive attitude about mathematics. Sophomore year geometry was an exception for a variety of reasons. She did not like the teacher and admitted that her friends often distracted her, as the class size was small. Megan also maintained that she was not good at geometry throughout her interview but did not elaborate on why she felt that way. After having a gap year in math, Megan began her college mathematics experiences with College Algebra. The class was difficult between having an adjunct professor without office hours and her mathematics gap year. However, the following semester, she retook the class and passed with “smooth sailing.” Megan majored in General Studies with a Mathematics Education minor, so her remaining mathematics courses were education-based.

Unlike the other participants discussed so far, Megan did not talk about any circumstances that she claimed made her love mathematics. Furthermore, she maintained that she liked mathematics, but she did not convey enthusiasm using vocal and facial expressions like some of the other participants. Perhaps outside factors contributed, but her interview and stories hinted at a mild lack of interest. When asked if she found
mathematics interesting, she responded that she had “always been good at math.” Therefore, Megan’s story, though featuring some change in attitude about math, did not possess a spark that made her love the subject.

Path Five: Almost Revelation. The final path observed in the data is a blend of Revelation and Sparkless. It features the fear or hate of the Revelation path followed by the student’s realization that they can be successful at math, but it lacks the spark that compels the student to love mathematics and pursue it further; hence, the defining feature of Sparkless. Hayley, Participant 6, was the representative of this path in the data. Before discussing Hayley’s mathematics story, it is important to note that Hayley and Nicole (Participant 5) attended the same high school and had the same teachers. This fact illustrates how different the paths students under the same conditions can take.

Overall, Hayley claimed that she had a positive experience with mathematics. She said she liked mathematics when it was easy, because she “enjoys the feeling of figuring out something complicated,” but when it was hard for her, she called it “the bane of my existence.” She did not remember much about her mathematics classes in elementary and middle school but considered it to be a “good” experience. In freshman year of high school, she took geometry with the mathematics teacher that Nicole disliked. She lost a lot of her confidence in mathematics during that school year and began doubting her capabilities. According to Hayley, her teacher had a lot of impatience and generally did not explain concepts or her reasoning behind her steps in mathematics problems well. In front of the entire class, she also made remarks to students such as “You’ll not make it in college” or “strongly implied you were stupid.” This continued the following year in her
Algebra II class with the same teacher. The whole class felt like “a separate language” to her, and little of the content made sense to her. “Each day was a nightmare,” she claimed, saying that “[I] Built my identity on being intelligent.” Even worse for Hayley was the fact that some of her classmates were doing well in the course. The two observations together made her believe she was actually dumb. Her confidence in her mathematical abilities which had lasted for years was destroyed by a single teacher.

In college, Hayley took two mathematics classes – College Algebra and Calculus I. After her experiences in high school, she was afraid of taking more mathematics classes, but her friend Nicole (Participant 5) offered to help her when needed. However, these classes helped Hayley rebuild her confidence in mathematics. Her College Algebra teacher was very thorough for she explained each step of a problem and beforehand, discussed what she was trying to accomplish (the point of the exercise). Hayley felt able to follow along in class, and as the teacher did not act judgmental about student questions, felt comfortable asking for clarification on anything that was not clear. Haley’s Calculus I course also unfolded similarly. When she was working homework problems for these classes, she would ask Nicole questions, and Nicole would then “explain like a teacher would.” Hence, between Nicole’s help and good college mathematics teachers, Hayley was able to repair her confidence in mathematics. Notice that while Hayley had a significant change in her feelings about mathematics, she did not have a spark that caused her to pursue mathematics further, by taking more classes, for example.
Comparison of Interview and Survey Data

As stated in Section 3, survey data (Appendix A) was compared to interview data in order to identify similarities in the data sets. Interestingly, survey participants claimed they felt their pre-college mathematics education “definitely prepared” or “somewhat prepared” them for college mathematics, which generally reflected the attitudes of interview participants, especially for Amy, Nicole, and Hayley. Additionally, 53% (15) of the 28 recorded responses for “Have your opinions about math changed in any way after taking college math courses?” indicated that students felt their opinions about mathematics had changed during college. Emily’s, Madison’s, and Hayley’s stories reflected this idea of change as well. Amy’s story also reflected this aspect to a lesser extent. One other significant overlap between the survey and participant data sets involved the students’ current confidence in mathematics. All interview participants indicated that at the time of the interview, they felt comfortable about their mathematical skill level. Likewise, “Somewhat Confident” and “Very Confident” at 56.67% and 30.00% respectively were the most popular responses to the parallel question in the survey. Therefore, survey results did verify some aspects of the interview data.

Returning to the interview data, five different paths were observed: Arrow, Improvement, Revelation, Sparkless, and Almost Revelation. In the next section, I will discuss the importance of these paths. Knowing which path a particular student follows may be the key to inspiring a love of mathematics.
Section 5: Final Conclusions

Limitations to research. This research was conducted at one university. While effort was made to interview students with a wide range of mathematical experiences and attitudes, I was unable to interview a student who completely disliked the subject. Additionally, as students are individuals with unique stories, it is impossible that the paths uncovered in the data represent all students’ journeys through their mathematical educations. While this study is small, it does provide evidence for just how sensitive students’ attitudes about mathematics – both positive and negative ones – are to outside influences, such as class content and teachers. Almost nothing is “set in stone,” so to speak, with attitudes about mathematics.

Implications for Practice

In the previous section, I outlined five possible paths that students may take in their mathematical education. Conclusions now may be drawn from these paths. In this section, I will discuss the implications of this research for mathematics education as well as provide ideas on how to inspire a love of mathematics in students.

Path Sensitivity. One of the most interesting results from this study was how sensitive most of the paths were to various mathematics circumstances, especially negative ones. Examples include experiences with teachers, classes, etc. In each of the
mathematics stories examined in Section 4, students were able to describe specific memories in detail where they felt “dumb,” upset, or other strong emotions regarding mathematics. The students appeared to internalize these incidents and consider them personal insults. As in the case of Hayley, one negative mathematics experience can undo years of positive experiences. Students, mindful of that incident, may refuse to apply themselves in mathematics again in the future.

However, the damage from negative experiences can be undone. As Madison’s and Emily’s stories show, even the most stubborn, self-professed “mathematics hater” was still able to be influenced into liking math. Therefore, student feelings coupled with mathematics experiences is a dramatic, very sensitive thing that almost contradicts itself.

In the following subsection, I will discuss the type of student who experienced negative emotions but still loved math. These students’ resolves were steel, and the negative experiences did not permanently change their feelings about mathematics. This is the Arrow path student with positive feelings. By examining this path, one can see the importance of enjoying mathematics. When mathematics becomes difficult (and it does for most, whether the topic is fractions in 4th grade or senior year topology in college), passion for the subject will force this type of student to keep pursuing her mathematical goals.

**Importance of the Arrow Path.** The group mentioned above, Arrow path students with positive feelings (denoted as positive Arrows), shows why it is important to make mathematics enjoyable. Recall that students with Arrow paths are generally the most stable with their feelings about mathematics, whether those happen to be positive, neutral, or negative. As suggested in the data by analyzing Nicole’s story, positive
Arrows are not easily deterred in their love for the subject. While other paths are very sensitive to “bad” experiences – whether that involves teachers, class material, test anxiety, etc. – this type of student often becomes ingenious in discovering ways to counteract obstacles he or she encounters. When Nicole had difficulty in her calculus course because of her teacher, she did not allow her negative experience to change her opinion of the subject. Instead, she found ways to teach the material to herself through YouTube and other online resources. For an entire school year, Nicole taught herself and her classmates calculus simply because she loved mathematics and wanted to understand. When she had difficulty in her first proof-writing course (a challenging class for many mathematics majors) and began to feel anxious, she again acknowledged her negative feelings and continued to persist.

Positive Arrow students are not afraid of negative mathematical experiences. While they may have periods of fear, dislike, or anxiety about mathematics, they do not allow the feelings to overwhelm and change their overall opinion of mathematics. Like Nicole, their interest and love for the subject is unwavering, and they are motivated to do well in mathematics. This may include finding a tutor, spending extra time studying on their own, attending office hours, or finding online resources to help themselves. These students will most likely do well, because they are prepared to take the initiative in their education when challenges arise. While other paths are sensitive to negative mathematical experiences, positive Arrows persevere because they love mathematics.

**Inspiration of the Revelation Path.** While the positive Arrow path shows the importance of enjoying mathematics and demonstrates perhaps the ideal mathematics student, the Revelation path may provide clues as how to actually transform attitudes. In
this section, I will generalize the overall Revelation path in a way that may be useful for helping students change their attitude about mathematics.

“The Necessary Evil.” In both of the Revelation path stories analyzed, the student begins her path to a newfound love/appreciation of mathematics in the “Necessary Evil” Stage – mathematics is very bad at this point, but the student has no choice but to engage with the subject for her personal goals. In Emily’s case, this goal was to pass her student-teaching component; in Madison’s, it was to fulfill requirements of the business major. At this point, the student is forced into mathematics somewhat unwillingly. While she is motivated to “get through,” to use Emily’s words, she is not excited about the upcoming experience and may treat it with an impending sense of doom.

“Tough Love.” Once the student has started her mathematics experience, however unwillingly that may be, she encounters some sort of mathematics authority figure, who does not accept her current attitude about the subject. This may be in a demanding, no-nonsense manner, like Emily’s professor. The professor told Emily that she had to do her student teaching in 5th grade mathematics and did not accept Emily’s ideas that she did not understand math. Note that Emily’s high school physics teacher also adopted this attitude; he did not accept Emily’s lack of understanding and worked with her until she did understand. However, the authority figure may also choose a more passive route, as Madison’s Calculus III instructor did. This instructor made mathematics classes entertaining, with his likable persona and kindly attitude. Whatever the case, this mathematics authority figure challenges the student’s ideas about mathematics and
herself. The student realizes that maybe her thoughts about her relationship with mathematics is not entirely correct, which leads to the following subsection.

“Not-So-Bad.” After a while in her “Necessary Evil” mathematics experience and encountering the mathematics authority figure who challenges her ideas, the Revelation path student begins to think that mathematics is not so terrible after all. She would not claim she likes it, but at the very least, mathematics is bearable and perhaps interesting at times to her. Emily discussed a period of time in her student teaching where it was “not so bad.” She discovered that she was a better mathematics teacher than she thought and developed a connection with her students. Many of them had the exact same difficulties with mathematics that she did. Therefore, she was able to assist them and began to find the experience rewarding. Madison’s “Not-So-Bad” experience was her college calculus sequence. She was afraid of college mathematics classes, especially her first, business calculus. However, in every calculus course, she did better. This culminated in her Calculus III course. In this stage, students somewhat alter their preconceptions of mathematics.

“Moment of Realization.” In this stage, the student makes a shocking discovery – that she actually is enjoying mathematics. She is awestruck, as this revelation may hit her suddenly. Her family and her friends are mystified. For Emily, this moment of realization appeared to be when she developed empathy for her students. By spotting their problems and then attempting to help, Emily was able to be the teacher for her students that she wished her teachers had been for her. She loved their excitement when they finally understood something, and this in turn, gave her positive feelings about mathematics and teaching the subject. For Madison, her moment of realization was a
little less clear-cut, but two possible moments exist. One was her experiences in Calculus III with the sequences and series problems. For the first time, she was answering yes-or-no questions that appealed to her and were different from anything she had previously studied in math. The other candidate moment was when she realized that she would miss doing mathematics after her required classes were finished. Rather than pick another program without mathematics, Madison elected to pursue a mathematics major, even though she felt timid about her choice. Regardless of how the moment occurs, the student realizes she enjoys the subject and then must make a decision what to do about her realization.

“Happily Ever After” The final step is when the student decides to further pursue mathematics in whatever context she chooses. In Emily’s case, she decided to teach mathematics herself. In Madison’s case, she became a mathematics major. The Revelation arc is complete, and the student now enjoys mathematics and is determined to explore her newfound interest.

How to Make Students Enjoy Mathematics: Applying the Results

If one accepts the above Revelation path as a reasonably accurate model, then one may be inspired to incorporate elements of it into mathematical education. Key components of the arc are the student’s forced position into a mathematical experience, the mathematics authority’s attitude, and finally, the “showing-and-telling” that mathematics is not terrible during this experience.
Students who do not like mathematics generally do not want to do mathematics and will not seek out opportunities to do so. Therefore, it is important that students be “forced” into mathematical experiences for a change in attitude to occur. The word “forced” is a little misleading, as already students are required to take mathematics classes for twelve years of their education and do not necessarily come out of that experience loving mathematics. Rather, the student needs to be given some motivation for engaging with the subject. As suggested by the study data, program requirements is one effective, if not extreme, way to do this. Milder ways to motivate students into mathematical experiences could be incorporating more applications of topics studied, providing interesting mathematical concepts in terms of puzzles or games, or other such teaching methods.

Of course, the motivation for a mathematical experience will not help the student much if her fundamental ideas about herself and mathematics are not questioned and ultimately rebuilt. A mathematics authority figure, commonly the teacher or instructor, needs to challenge what the student thinks about her relationship with mathematics. Many consider themselves to “not be mathematics people.” An instructor must challenge this idea. Examples may be encouraging a healthy mindset in mathematics class. Teachers can show belief in their students by correcting them when students claim they cannot do it or vocalize their beliefs of not being “mathematics people.” Whatever a teacher can do to encourage a class to be open-minded is a powerful way to reshape student attitudes about mathematics and question their current relationships with the subject.
Finally, teachers must exemplify what a good relationship with mathematics is. The teacher cannot be afraid of the subject or openly display doubts about his or her own abilities. Teachers must project confident, upbeat attitudes about the subject, even if that does not entirely reflect how they themselves feel about mathematics. One such example is Madison’s Calculus III teacher. His cheerful attitude about mathematics influenced how Madison viewed the subject. If teachers do not believe in their mathematical abilities, how can students, who observe how the teacher speaks about, feels, and teaches mathematics? Thus, having a good attitude is also necessary.

**Implications for Future Research:** Analyzing student mathematical stories provides valuable insight into what is working or not working well in current mathematics education. Observing what teaching methods and ideas effectively helped students, teachers can reconstruct mathematics education in a way that makes it a less despised subject. Student stories may be the key to fixing the current problems. Future research in this area should make use of such a valuable source of information. Researchers should collect more stories for analysis and define more paths until all students are represented. This more individualized approach suggests ways to help specific groups of students learn to enjoy mathematics – what may work well for one group may not help another. Another interesting research question that emerges from this thesis is testing if more collected Revelation path stories uphold or contradict the provided Revelation path arc. If not, future research could modify or replace it with a better model of such student mathematical stories. This sort of research is necessary, as this kind of story provides many clues to help students change their attitudes about mathematics. Students want to be heard; it is time to start listening.
Conclusion

Mathematics does not necessarily need to be “fun.” It is a serious field of study and an important classroom subject that students will use the rest of their lives, whether they like the idea or not. Not every student needs to find it entertaining and as a result, become a mathematician. The true purpose of helping students enjoy mathematics is not for mere entertainment value, but rather cultivating in them a spark, a passion, for the subject. Those who have a passion for mathematics do not give up when it becomes challenging. They do whatever they must to help themselves understand, and eventually, they will succeed because failure is not an option for them. This is the true value of enjoying mathematics. Ultimately, it is more important to focus on enjoyment rather than achievement. If teachers truly wish to improve their students’ accomplishments in mathematics, they must first discover how to ignite in them a love of mathematics. How can teachers possibly hope to change student attitudes? It all begins with a spark.
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Appendix A

Survey Questions for Participants:

1. Are you over 18 years of age?

2. Results of this survey may be used in a SMBHC senior capstone thesis. Results may also be used in a publication/presentation. Do you agree with these terms?

3. What areas of math did you find the most difficult (fractions, geometry, etc.)?

4. Have you experienced any sort of anxiety over math (such as dreading going to class, severe anxiety before a test, etc.)?

5. If you have had trouble with math, what do you think helped cause it?

6. Did you have good support in grade school math? Were teachers or other adults with math expertise available to you for extra help?

7. On a scale of 1 to 5, with 5 being most satisfactory, rate your general math class experience for each of the following: elementary school, middle school, and high school.

   1—Very Dissatisfied  2—Dissatisfied  3—Neutral  4—Satisfied  5—Very Satisfied

8. How confident do you feel about your current mathematical abilities, on a scale from 1-5?

   1—Very Unconfident  4—Somewhat Confident

   2—Somewhat Unconfident  5—Very Confident

   3—Neutral

9. Which do you like more? Doing math assignments in groups or doing math assignments by yourself? Why?

10. Did you feel overall prepared for college math?

11. Have your opinions about math changed in any way after taking college math courses?
12 Would you be open to being interviewed? If so, please provide your email address.
Appendix B

Interview Questions for Participants:

1. Results of this interview may be used in a SMBHC senior capstone thesis. Results may also be used in a publication or presentation. Any identifying information (names, places, etc.) will be removed. Do you agree with these terms?

2. What do you think your math teachers could have done differently to help you (specific grades or in general)?

3. What age or grade did you have trouble in math? Why?

4. Tell me about your strongest math memories. Tell me about your favorite math memory.

5. Tell me about a time you found math difficult.

6. Tell me about your favorite math teacher.

7. Tell me about your college math experiences.

8. Tell me about how you studied for math. What kinds of activities and resources did you use (memorization-oriented activities, manipulatives, games, etc.)?

9. Have you had any negative feelings towards math (frustration, anxiety before tests, dread about going to class, etc.)?

10. Who has helped you with math besides teachers? What was their skill level in math?