INFLUENCE OF PRESERVICE ELEMENTARY TEACHERS' MATHEMATICS EXPERIENCES ON THEIR ATTITUDES AND BELIEFS ABOUT MATHEMATICS

By

Kevin J. Voogt

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ABSTRACT

INFLUENCE OF PRESERVICE ELEMENTARY TEACHERS' MATHEMATICS EXPERIENCES ON THEIR ATTITUDES AND BELIEFS ABOUT MATHEMATICS

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Mathematics education research has repeatedly shown that many elementary teachers and preservice elementary teachers (PSTs) carry negative attitudes and unhealthy beliefs about mathematics (e.g., Bursal & Paznokas, 2006). That research, however, has largely examined PSTs' attitudes and beliefs about mathematics separately, rather than together, ignoring the research that has long asserted a relationship between the two (e.g., McLeod, 1992). Also, it has mostly focused on dislike of mathematics or mathematics anxiety, rather than attending to the full range of attitudes, including positive ones. Lastly, attitudes have largely been examined holistically. While students may have a predominantly positive or negative attitude toward mathematics, they may also like or dislike particular aspects of mathematics.

In this study, I examined the attitudes that a group of PSTs held toward mathematics concurrently with their beliefs about mathematics. I also explored the experiences they indicated had shaped those attitudes and beliefs. Lastly, I examined their "turning point stories," or experiences that brought about significant change in attitudes or beliefs (Drake, 2006), to track the most drastic changes in their attitudes. I used qualitative research methods to explore a range of written and spoken data that addressed these issues—including mathematics autobiographies, free-response survey questions, and interviews in which participants graphed their changing attitudes over time.

Findings indicate that these PSTs' attitudes and beliefs were interrelated, complex, and not easily captured by force-choice or Likert-type survey items. These PSTs' attitudes and

beliefs fluctuated based on their experiences with mathematics, especially as connected to teachers and performance outcomes. This group also reported their attitudes as more positive than negative, though the data also suggest complexity about how they selected their attitude ratings. Findings also indicated that many PSTs had come to their teacher preparation program with beliefs about mathematics that were directly oppositional to some of their peers (e.g., only one solution path for solving a problem versus many possible paths). PSTs at all levels of attitude (i.e., liking or disliking mathematics) reported negative experiences with mathematics, where some categories of experiences were either generally positive (e.g., working with a tutor) or negative (e.g., taking mathematics tests). Positive turning points in attitudes toward mathematics were located in high school and college, whereas negative turning points were reported across all levels of schooling. PSTs most-often described their experiences with mathematics as a "roller coaster," with teachers being the most-common cause of turning points in their attitudes toward mathematics.

These results have important methodological, pedagogical, and theoretical implications for research on preservice elementary teachers' attitudes and beliefs about mathematics. First, simple or Likert-scale surveys may obscure the complexity and dynamic, changing nature of people's attitudes and beliefs about mathematics. This study provides some methodological alternatives. For instruction, teachers hold substantial power in shaping their students' attitudes and beliefs about mathematics, but teacher preparation programs can be a site of recovery. In exploring the relationship between attitudes, beliefs, and experiences, this study suggests focusing future research on the dynamic, multidirectional relationships among the three.

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KEY TO ABBREVIATIONS

PST	Preservice Elementary Teacher
SQ	Survey Question
[word]	Additional word(s) for sake of clarity, not said by participant

CHAPTER 1: Introduction

The Association of Mathematics Teacher Educations Standards for Teacher Preparation states that "All teachers, including well-prepared beginners, must hold positive dispositions about mathematics and mathematics learning, such as the notions that mathematics can and must be understood, and that each and every student can develop mathematical proficiency" (AMTE, 2017, p. 7). The elementary teacher population is unique as they are primed to teach a variety of subjects but may not enjoy mathematics as much as those at the secondary levels who are required to specialize in their subject areas. As Wood (1988) put it, "elementary teachers are charged with an extremely important role…to engender an excitement for learning in all subject areas, including mathematics" (p. 11). They should exhibit more excitement, a better attitude, and more comfort with mathematics than the general public.

Research, however, has indicated that many elementary teachers and preservice elementary teachers (PSTs) carry negative attitudes and feelings about mathematics themselves (e.g., Bursal & Paznokas, 2006; Johnson & vanderSandt, 2011; Kelly & Tomhave, 1985; Kolstad, Hughes, & Briggs, 1994) and hence may be influencing their students' dispositions negatively by displaying said negative feelings or a lack of confidence while teaching (Liu, 2008; Martinez 1987; Voogt, 2018). Hence, finding ways to better understand and improve preservice elementary teachers' dispositions toward mathematics would be an important consideration in all elementary teacher preparation programs.

Research on the affective domain in the teaching of mathematics has improved in recent years (Middleton, Jansen, & Goldin, 2017), and multiple researchers have identified *emotions*, *attitudes*, and *beliefs* as major subdomains of affect, while also noting an intimate, connected relationship between the three (e.g., McLeod, 1992; Philipp, 2007). Emotions have received less attention as they have been understood to be temporary *states* of affect, whereas attitudes and beliefs have been seen as more stable *traits* of affect and hence have received more attention in research (McLeod, 1992; Philipp, 2007). McLeod (1992) offered an example to illustrate the intimate relationship between these three constructs. If a student believed mathematics is a subject requiring quick responses and found himself struggling with a problem, he may react negatively emotionally to the situation. If he encounters such problems repeatedly, he may develop a negative attitude toward mathematics due to the disconnect between his beliefs about the nature of mathematics and his experiences.

For the purposes of this study, I utilized the following definitions of attitudes toward, and beliefs about mathematics, which I have drawn mostly from the work of prior mathematics educators and researchers, such as Philipp (2007) and McLeod (1992), but with necessary changes for clarity. They are as follows:

> **Attitudes toward Mathematics** – Judgements about mathematics that reveal one's disposition toward it. They can be positive, negative, or neutral. Attitudes are more stable and cognitive than emotions, but less cognitive and can change more quickly than beliefs (McLeod, 1992). Attitudes can be signified with binary words such as like or dislike, preference or non-preference, love or hate. For the purposes of this study, "attitudes toward" mathematics is seen as synonymous to "feelings about" mathematics when feelings are sustained past a momentary – which would be emotional – state.
>
> **Beliefs about Mathematics** – Cognitively-held understandings that are thought to be truths about mathematics. Beliefs may be stated as if true for everyone (even if not the case – e.g., mathematics is about memorizing rules) or true only for oneself (e.g., mathematics is a boring subject). They are not consensual. Beliefs have been seen to be

more stable than attitudes but may be more subtly felt than attitudes (Philipp, 2007).

Examples of positive attitudes include liking geometry or preferring algebra. Examples of negative attitudes include hating proofs or disliking calculus. Indifference toward something is an example of a neutral attitude. Beliefs can be general (thought to be true for everyone) or personal (recognized by the individual as not consensual). An example of general beliefs about the nature of mathematics might be that mathematics is all about problem solving. Examples of personal beliefs about the nature of mathematics is that mathematics is hard or is fun. Attitudes can be influenced more by particular emotional experiences, whereas beliefs are held more strongly and are more-often developed over longer periods of time, which some have argued make them difficult to change (e.g., McLeod, 1992).

Though many researchers have examined PSTs' attitudes and beliefs, they have often done so isolating each construct and by using quantitative measures, such as Likert scales or other force-choice surveys (Philipp, 2007). Likert-scale and force-choice surveys, however, capture momentary attitudes and offer choices from a pre-selected list of possible beliefs. They fail to capture the development of the attitudes and the full range of beliefs. Researchers have also developed multiple interventions in PSTs' mathematics content or methods courses to change attitudes or beliefs about mathematics, but many did not base their interventions on research that has examined the experiences PSTs had prior to their preparation programs that shaped their attitudes or beliefs about mathematics in the first place (e.g., Dove & Dove, 2017, Gresham, 2007; Harper & Daane, 1998). The few studies that have focused on PSTs prior experiences examined only negative attitudes or unhealthy beliefs rather than positive attitudes and productive beliefs. In the most recent *Compendium for Research in Mathematics Education*, Middleton and colleagues (2017) echoed the need for future research to try to explore the conditions that bring about various attitudes and beliefs so that teachers can better understand them. By better understanding the K-12 influences on attitudes and beliefs about mathematics, teachers will be better equipped to identify the situations in their own classrooms that could either produce negative or promote positive attitudes and beliefs and hence intervene or encourage their students accordingly.

A number of studies have examined the effects of mathematics content or methods courses on preservice elementary teachers' attitudes toward mathematics (e.g., Dove & Dove, 2017; Jong & Hodges, 2013; Quinn, 1997). Few studies, however, have examined the experiences that may have shaped PSTs' attitudes and beliefs toward mathematics prior to entering their teacher preparation programs. Most of the studies that have attempted to understand such experiences have focused on negative attitudes, emotions, or dispositions, such as mathematics anxiety (e.g., Finlayson, 2014; Harper & Daane, 1998; Stoehr, 2017). Drawing conclusions from only examining the experiences of those with negative attitudes leaves questions about the validity of such studies. For instance, people with positive attitudes may have had similar experiences to people with negative attitudes and hence are informed in other ways than what prior research has indicated. Also, there is a lack of research on PSTs' attitudes and beliefs about mathematics where both constructs are examined within the same population. Due to the intimate relationship between attitudes and beliefs theorized by a number of scholars (e.g., McLeod, 1992; Middleton et al., 2017), it is important to explore the possible relationships between them.

CHAPTER 2: Background Literature

In this chapter, I review the research literature that has examined preservice elementary teachers' attitudes and beliefs about mathematics. I examine each construct separately, describing them more generally before reviewing the research that examined the pre-service elementary teacher population (PSTs) specifically. The research below includes both U.S. and international contexts.

Attitudes About Mathematics

Many students hold negative attitudes toward mathematics, seeing mathematics as useless, not worthwhile, and coupled with a fear of mathematics and low self-efficacy (Geist, 2010). Many of the reasons for students' negative attitudes toward mathematics are related to their experiences with their schooling, including the use of timed tests, competitive mathematics games, emphasis on memorizing formulas and multiplication tables, and their teachers' difficulty addressing their questions (Harper & Daane, 1998; Jackson & Leffingwell, 1999; Voogt, 2018). Research has also shown that teachers' attitudes not only can impact their instructional practices, but also the attitudes of their students (Young-Loveridge, Bicknell, & Mills, 2012).

Preservice Teachers' Attitudes. Young-Loveridge and colleagues (2012) found through surveys that nearly half of their PST participants reported disliking mathematics during their time in secondary school, with many attributing their dislike of and difficulties in mathematics to their primary and secondary teachers. Jong and Hodges (2013) also utilized a survey and found that 39% of their 146 participating PSTs entered their teacher preparation program with negative attitudes toward mathematics. They also found that PSTs' initial attitude toward mathematics was a better predictor of their attitude toward mathematics after completing their teacher preparation programs than were grades in their mathematics methods courses. Foci in their methods courses, such as utilizing multiple representations and various instructional strategies were measured on a separate scale, but prior attitudes were more influential on their post-attitudes. While in these studies a majority of PSTs indicated indifference or positive attitudes toward mathematics, both focused on only those participants with negative attitudes.

Mathematics Anxiety. In mathematics education, one would be remiss discussing preservice elementary teachers' attitudes toward mathematics without including mathematics anxiety research. *Mathematics anxiety* includes negative feelings such as discomfort, dread, or fear of mathematics (Bursal & Paznokas, 2006; Gresham, 2007). As a consequence, mathematics anxiety can lead to avoidance behavior, tension, worry, and lower achievement in mathematical situations (Bursal & Paznokas, 2006; Geist, 2010). As it has been generally researched and described, mathematics anxiety qualifies as a more steady affective trait, and hence as an *attitude* rather than an emotional state (Middleton et al., 2017). It should not be conflated with the colloquial meaning of anxiety, which is more often associated with a temporary emotional or physiological state. Though both consist of feelings of worry, unease, or avoidance behaviors, mathematics anxiety as it has been researched has more stable characteristics than the emotion of anxiety.

Research has indicated that PSTs experience mathematics anxiety at particularly high levels (Bursal & Paznokas, 2006; Johnson & vanderSandt, 2011; Kelly & Tomhave, 1985). Kelly and Tomhave (1985) found evidence that PSTs exhibited higher mathematics anxiety than other college students who had the potential to be mathematics anxious (freshman with no college preparatory mathematics courses, freshman in college algebra, seniors with no college mathematics courses, and students enrolled in a workshop specifically for the mathematics anxious). Bursal and Paznokas (2006) found that nearly half of their PSTs who exhibited high mathematics anxiety also lacked confidence to teach elementary mathematics, reporting that their results align with other studies that higher mathematics anxiety causes lower confidence to teach elementary mathematics. Johnson and vanderSandt (2011) found that deaf and hard of hearing and early childhood preservice teachers reported higher levels of mathematics anxiety than special education or elementary preservice teachers, but all four groups exhibited high mathematics anxiety regardless of their educational major.

Researchers have employed different methods to explore the factors that influenced PSTs' mathematics anxiety. Harper and Daane (1998) utilized a checklist that included aspects of school mathematics, like word problems, focusing on right answers and methods, timed tests, and solving mathematics problems. Three other studies employed open-ended qualitative approaches and found more emotional (e.g., self-confidence, fear of failure, feeling left out due to ability grouping) and environmental (e.g., teacher factors) influences on participants' mathematics anxiety (Finlayson, 2014; Stoehr, 2017; Wilson, 2015).

These studies have often pointed to teacher factors (e.g., teaching style, teacher criticism) as leading to the development of mathematics anxiety. Test anxiety and test scores were also indicated by multiple studies as bringing about mathematics anxiety (Stoehr, 2017; Wilson, 2015). Harper and Daane's (1998) aforementioned checklist revealed word problems – including how long it takes to solve them, an emphasis on right answers and using certain methods, and fear of making mistakes as most influential for their population of preservice teachers.

Summary. As seen above, much more emphasis has been given to the negative attitudes of PSTs, especially mathematics anxiety, than positive. Both Young-Loveridge and colleagues (2012) and Jong and Hodges (2013) examined their PSTs' attitudes, but focused their analysis and report of data on reasons for poor attitudes rather than examining the majority of PSTs in their studies, who were either indifferent or liked mathematics. In the mathematics anxiety literature, the focus is solely on the existence of PSTs' dread, fear, or avoidance of mathematics and the experiences that brought about those feelings. This study sought to examine the full range of attitudes toward mathematics to gain insight into the experiences that informed both like and dislike of mathematics and see what sort of experiences have influenced attitudes in either direction.

Beliefs

In this study, I focused on beliefs about the nature mathematics, as opposed to beliefs about mathematics teaching and learning. A large body of research has pointed to an important relationship between teachers' beliefs about the nature of mathematics and classroom instruction (e.g., Ernest, 1989; Philipp, 2007; Putnam, Heaton, Prawat, & Remillard, 1992). Though beliefs about how to teach or learn mathematics are important, research has argued that often it is teachers' beliefs about the nature of mathematics that more greatly influence their practice than their beliefs about how to learn or teach mathematics, as beliefs about how to learn or teach mathematics are often overshadowed by more general constraints of the teaching setting and school requirements (Philipp, 2007; Raymond, 1997). For example, if teachers believed mathematics to be boring and difficult by nature, they might design their teaching to make it more exciting, despite risking confusing the mathematics in the attempt (Ball, 1988; Putnam et al., 1992).

Ernest (1989) outlined three types of beliefs about the nature of mathematics: (a) the instrumentalist view of mathematics as the collection of facts, rules, and skills, (b) the Platonist view that mathematics is a discovered, unified body of certain knowledge, and (c) the problem-solving view of mathematics as a cultural product, a continually expanding endeavor of human creation and invention. In (b), mathematics is a finished product that is uncovered over time whereas in (c), it is unfinished and open to revision. Ernest argued that the way teachers approach mathematics teaching depends necessarily on their beliefs, in particular on their beliefs about the nature of mathematics. Research has reported that elementary teachers often think of mathematics in terms of (b), calling it a “universal language” or the language of nature (Katmer-Bayrakli & Erisen, 2019; Latterell & Wilson, 2016; Sterenberg, 2008).

Ernest (2004) expanded those three basic beliefs with descriptions of the absolutist and fallibilist views of mathematics. The absolutist view is that “mathematics is certain, cumulative and untouched by social interests or developments beyond the normal patterns of historical growth” (p. 6). It rests firmly on the truths of deductive logic. In essence, mathematics exists as it should exist, and we are uncovering its truths over time. The absolutist view could be seen as a combination of (a) and (b) from Ernest (1989). The fallibilist view, on the other hand, is that mathematics is historically and socially constructed, is malleable and changeable, and can change based on cultural or other influences and, hence, is “eternally open to revision” (Ernest, 2004, p. 9). In this case, mathematics has been created over time, but by no means is it without the possibility of refutation and change, much like Ernest’s (1989) belief (c) above.

Schoenfeld (1992) also emphasized the social construction of mathematical knowledge, and that mathematics is a practice carried out by a community engaging in the science of patterns. Other researchers and mathematicians have likewise purported that mathematical knowledge is socially constructed (Burton, 1998; Cobb, Yackel, & Wood, 1993). In this belief, mathematics is not a set of rules to be memorized but rather should be seen as a set of ideas that are socially constructed and negotiated. Hence, this belief about the nature of mathematics is not unlike Ernest’s (2004) fallibilist view.

Another traditional belief about the nature of mathematics, often reinforced by experiences in school mathematics, is that doing mathematics is about completing tasks or procedures quickly and accurately (Schoenfeld, 1988; Shah & Leonardo, 2017). This was evidenced in Schoenfeld's (1988) study when students spent more time making sure their geometric proofs were in the correct format than solving proof problems themselves. The classroom teacher in this study emphasized that what mattered in students' geometric constructions was the accurate repetitions of the procedures he taught. Students in his classroom believed mathematics was more about the form of its expression than about understanding it. Schoenfeld argued that in traditional school mathematics students saw themselves more as "passive consumers of others' mathematics" (p. 165). This was further confirmed by the results of a survey provided in Schoenfeld's (1988) study, where students agreed most strongly with "the mathematics I learn in school is mostly facts and procedures to be memorized" (p. 161).

Preservice Teachers' Beliefs about Mathematics. Relatively little attention has been given to preservice elementary teachers' beliefs about the nature of mathematics. More research has focused on PSTs' beliefs about teaching and learning mathematics than it has on their beliefs about the nature of or what it means to know mathematics. Several researchers have attempted to learn about PSTs' beliefs through the metaphors they used in describing mathematics. Cassel and Vincent (2011) found that PSTs' metaphors suggested that mathematics was mostly about end-products (e.g., getting a right answer) than a process or an exploration. Latterell and Wilson (2016) found the opposite – PSTs in their study used metaphors describing mathematics as the process of solving problems and that learning happens through that process. Their PSTs also viewed mathematics as like a puzzle with problems to which one has to figure out the solutions, which is not unlike how mathematicians have conceptualized mathematics (Burton, 1998).

Metaphors also have pointed to PST views of mathematics as a "universal language," implying that mathematics has a foreign aspect to it while also something absolute for everyone who learns it (Latterell & Wilson, 2016; Sterenberg, 2008).

Sigley, Alqahtani, Zied, Widdall, and Hewer (2019) used eliciting personification as a means for studying PSTs' beliefs about mathematics. This technique involved having their participants give life-like traits to a character called "Mathematics." Their PSTs viewed mathematics as an activity that only happens in schools. They reported mathematics to be logically structured and containing problems with only one correct solution path. Contrary to the studies listed thus far that mostly align with Ernest's (1989) instrumental and Platonist beliefs about mathematics, the preservice elementary mathematics teachers who participated in Katmer-Bayrakli and Erisen's (2019) interviews believed that mathematical knowledge was dynamic and changeable and that rules or formulas simplify mathematics but were not necessary. They viewed mathematics as a science that "is everywhere and in everything in nature" (p. 1555) and as an avenue for creativity and imagination. Hence, the views of these PSTs aligned more with Ernest's problem-solving view of mathematics. The PSTs in Katmer-Bayrakli and Erisen's (2019) study were in the final year of their teacher preparation program and acknowledged that their beliefs had changed due to their training, likely accounting for the difference in views from Sigley and colleagues' (2019) PSTs, who had yet to take any teacher education classes.

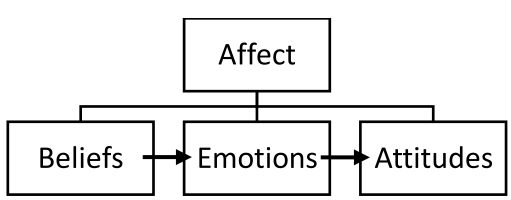
Summary. As mentioned previously, though ample attention has been given to students' and teachers' beliefs about the nature of mathematics, relatively little attention has been given to PSTs' beliefs. The small number of studies that has examined their beliefs seem to contradict each other. Also, though the studies on PSTs' beliefs above were explored using relatively open qualitative methods, many of them failed to examine or report the experiences that shaped PSTs' beliefs about the nature of mathematics in their own words. Beliefs were also examined in the those studies as an isolated construct. As mentioned previously, since attitudes and beliefs have been theorized to be related (see McLeod, 1992), it would be important to understand what relationship, if any, exists between them within a population and to seek the experiences that might have concurrently or separately informed them.

Theoretical Framework

McLeod (1992) theorized that the mathematics-related affective domain is comprised of three central constructs: attitudes, beliefs, and emotions. His goal was to develop a framework for affect that was consistent with mathematics education research that focused on cognition. He characterized beliefs as the most stable, cognitively-held construct with emotions on the other extreme (unstable, least cognitive), and attitudes falling in the middle of the two. McLeod not only established these three as composing affect, but also established important relationships between them. Beliefs were seen as informed by social contexts and experiences. Beliefs, in turn, underlay one's emotional reactions. If one's experiences did or did not align with one's beliefs, they could trigger an emotional reaction. Repeated emotional reactions or reinforcement of various emotions could, in time, develop attitudes. Figure 2.1 provides a model that illustrates McLeod's theorized components of affect and their relationship to each other as I saw it.

Figure 2.1

Model of McLeod's (1992) framework for affect in mathematics education.



According to this perspective, then, beliefs are foundational in the formation of attitudes. As an example, if a student believes that doing mathematics well means being able to do it quickly, he may become frustrated at being eliminated early in the mathematics racing games his teacher employs. Repeated frustrations (e.g., not finishing his timed tests, more competitive failures) may lead to a more established negative attitude. On the positive side, a student with similar beliefs who finds herself finishing tasks before her peers could experience satisfaction or joy. Repeated experiences of such emotions then could assist in establishing a positive attitude. Hence, I see it as imperative to not separate attitudes and beliefs, as has often been done in prior research, but include both of them, especially in the study of attitudes. As discussed earlier, because emotions have been seen to be more temporary and unstable, I chose to not include them as a focus of this research, especially since this research focuses on utilizing recalled experiences.

Conceptual Framework

The conceptual clarity around the meaning of attitudes and beliefs in educational research is murky, at best. While attitudes have a long history as a topic in education research, there does not seem to be a consistent definition of attitude developed by researchers. One of the oldest definitions of attitude, offered by Allport (1935), concentrated on how one's mental state affects one's behaviors in the social world. More recently, McLeod (1992) defined attitudes as the "affective responses that involve positive or negative feelings of moderate intensity and reasonable stability" (p. 581) and included such feelings as like and dislike, curiosity, and boredom. Zimbardo and Leippe (1991) defined attitude as being multifaceted and considered one's cognition, affective reactions, behavioral intentions, and past behavior as factors affecting one's disposition toward some object.

In mathematics education research, several researchers have likewise considered mathematics attitude as having a multifaceted structure. Watt (2000) contended that mathematics attitude consists of perceived ability, subject liking, expected success, interest, and utility. Meelissen and Luyten (2008) identified four aspects of mathematics attitude: self-confidence beliefs, liking (or disliking) of mathematics, perceived relevance of mathematics (either generally or in relation to career aspirations), and perceived stereotyped views on mathematics (e.g., as a male domain). Di Martino and Zan's (2010) model depicted attitude towards mathematics as the composition of and interplay between one's emotional disposition towards mathematics, their vision of mathematics, and their perceived competence in mathematics.

As stated previously, my conceptualization of attitudes toward mathematics is that they are one's judgements about mathematics that reveal their disposition, or feelings (e.g., like, dislike, neutral) about it. This conceptualization, like McLeod's (1992), is reasonably stable and includes both positive and negative feelings. Also, like McLeod, my conceptualization is not unidimensional, meaning people have many different experiences with and encounter different kinds of mathematics. Hence, one may dislike geometry and love algebra or dislike school mathematics and enjoy mathematics encountered outside of school. So while some people may indicate a dislike of all mathematics, some attitudes may depend on the specific mathematical topic, setting in which they experience the mathematics, or other factor. Hence, one could say they dislike mathematics, but still like certain aspects of it despite carrying an overall negative disposition toward it. This multidimensional characteristic of attitudes toward mathematics is why I use the plural *attitudes* in my definition, though when used, the singular "attitude" can be used to discuss a sort of average feeling toward mathematics on the whole or toward a topic or aspect of mathematics (e.g., attitude toward geometry).

My definition of attitudes does, however, differ from McLeod's. While McLeod included "being curious about topology" and "being bored by algebra" (p. 581) in his examples of attitudes toward mathematics, my conceptualization aims to simplify attitude with only statements or ideas that indicate disposition (like or dislike) toward mathematics or mathematical topics. Being bored by algebra may not reveal whether one likes it or not, and though being curious may indicate a positive disposition, it also may simply indicate inexperience with a topic. My definition more closely reflects the idea behind Di Martino and Zan's (2010, 2011) "emotional dimension" of their attitude model, which included words like hate, love, fear, and anger, though I also include neutral attitudes as well. Though those words do indicate emotions, and could be used to describe an emotional event, if they become a stable way of feeling about mathematics or mathematical topics they become what I am calling attitude (much like mathematics anxiety, as described previously).

Beliefs, despite also having a rich history, has also been variously defined and has sometimes been left undefined in research. As Thompson (1992) put it, "For the most part, researchers have assumed that readers know what beliefs are" (p. 129). Those who have defined mathematics beliefs or beliefs about the nature of mathematics have done so in different ways. Raymond defined mathematics beliefs as "personal judgments about mathematics formulated from experiences in mathematics" (p. 552) and included beliefs about the nature of mathematics as one aspect of mathematics beliefs. Katmer-Bayrakli and Erisen (2019) similarly based their definition on past experiences, defined beliefs about mathematics as the values and tendencies that grow out of those experiences.

It is difficult to distinguish those definitions from other constructs such as values, attitudes, or knowledge. Hence, I will attempt to bring some clarity to the conception of beliefs about mathematics. Thompson (1992) distinguished beliefs from knowledge in two important ways. First, beliefs can be held with different levels of *conviction*. One can be very committed to a point of view or only slightly convicted, whereas knowledge is not spoken about in such a way because it is a known truth. Second, beliefs are not *consensual*, whereas knowledge is. Philipp (2007) distinguished beliefs from values by pointing to dichotomies that exist within each. Beliefs hold a true/false dichotomy (for the individual, not consensually) whereas values hold a desirable/undesirable dichotomy. He stated, in distinguishing between the two ways we use the term belief colloquially, that "a belief *that* is about beliefs, but a belief *in* is about values" (p. 265).

Last, it is important consider the relationships and distinctions between attitudes and beliefs. Both constructs are informed by and brought about by past experiences (McLeod, 1992). McLeod (1992) argued that both constructs, along with emotions, comprise affect and that there is a sort of cognitive hierarchy between them. Emotions are the least cognitive and most temporary. If certain emotional experiences become a trend, such as consistently positive emotional experiences in algebra, they can develop an attitude, such as like of algebra. Attitudes are more stable and more cognitive and generally develop over longer durations of time and through more experiences than emotions (one experience can bring about a positive or negative emotional reaction). Beliefs are the most stable and most cognitive (they carry the least specific emotion) and are hardest to change because they take the most time and experiences to develop. Hence, I sought to understand the experiences that bring about attitudes and beliefs in my study, because without understanding the variety of PSTs' experiences, working productively with attitudes and beliefs would be very difficult.

Research Questions

In order to address the limitations in prior research discussed above, the purpose of this study was to explore the K-12 mathematics experiences of preservice elementary teachers that informed their attitudes (both positive and negative) and beliefs about mathematics. My specific research questions were:

1. *What is the overall landscape of attitudes toward mathematics amongst preservice elementary teachers?*
2. *What beliefs do preservice elementary teachers with positive and negative attitudes hold about the nature of mathematics?*
3. *What experiences do preservice elementary teachers attribute to having shaped their attitudes and beliefs about mathematics?*
4. *What types of experiences tend to be turning points in the mathematics attitudes and beliefs of preservice elementary teachers?*

By *landscape*, I include the range of their attitudes, changes in their attitudes over time, and any complexity that may exist within their descriptions of their attitudes. By *turning points* in my fourth research question, I borrow Drake's (2006) definition which is experiences or events that brought about significant change in attitudes or beliefs. I hypothesized my fourth question to be more easily answered with regard to attitudes, which have been theorized to be more easily influenced by particular events (see conceptual framework above) than beliefs, which are more cognitively held and more difficult to change. While the results of this study will suggest that beliefs may change more easily than hypothesized, it also suggests that, unlike attitudes, people generally hold multiple beliefs about mathematics at one time. Hence, measuring turning points (or major changes) in attitudes proved simpler (due to its binary nature) whereas measuring turning points in beliefs proved to be a more difficult endeavor as people hold multiple beliefs simultaneously.

This work contributes to mathematics education research in multiple ways. First, it attempts to describe PSTs' attitudes toward mathematics beyond the result of a Likert-scale survey choice. Second, this work seeks to understand what events or experiences influence both positive and negative changes in attitudes toward mathematics. Third, it examines the beliefs PSTs hold currently or have held prior to their teacher preparation, and it seeks to describe the relationship between their attitudes and beliefs. Lastly, it seeks to understand factors that had major impact (turning points) on attitudes and beliefs.

Insights from this work could benefit elementary content course developers in better understanding the beliefs and attitudes of incoming students and in supplying ideas for course activities or interventions that could support positive changes in them. Lastly, these results may also be of interest to educational psychology researchers, as it seeks to not only understand what attitudes and beliefs about mathematics people may hold but also unpack the genesis of their attitudes and beliefs about mathematics.

CHAPTER 3: Method

In this chapter, I outline and justify the methods I used to answer my research questions, including descriptions of the setting and participants, data sources, methods of data collection, and the pilot study that informed the study. The description of the data analysis is given in the following chapter.

Setting and Participants

This study engaged two participant groups – the whole group and a subgroup of interviewees. In this section I will outline the whole-group participant selection process and setting, describing the interviewee selection in a later section. The whole-group participants were recruited in person across five sections of the second of two mathematics content courses required for students pursuing PreK-6 teaching degrees at a large Midwestern university. I asked the instructors of each section if I could visit their class to talk to their students about my research and ask for permission to read an analyze two assignments I had designed for use in the course – a mathematics autobiography and follow-up survey (described later). Participants signed a consent form to indicate whether or not their assignments could be read by an external researcher, and I also asked for participants to signal whether they would be willing to participate in follow-up interviews.

N = 112 of the undergraduate preservice elementary teachers in those five sections consented to participate, with a relatively even distribution – {24, 19, 23, 25, 21} – across them. All but two of the PSTs' ages ranged from 18 to 22, and most were in their freshman (n=31), sophomore (n=47) or junior (n=27) year of college. One participant was aged 30 and one participant's age was unspecified. All but six of the 112 participants identified as female, five as male, and one was unspecified. They reported majoring in elementary education (n=81), special education (n=29), or early childhood development (n=2). All identifying information of participants was kept secure on a password-protected computer and persons' names were replaced by unique participant numbers.

Data Sources

The data sources consisted of a brief questionnaire that asked for some basic identifying information given to the whole group of PSTs, two writing assignments given to the same group, and follow-up interviews for selected participants. The writing assignments were (a) a mathematics autobiography where students characterized their relationship with mathematics from as far back as they could remember until the time at which they wrote, and (b) a series of free-response questions to which they provided short (1-2 sentence) answers. These two pieces of writing were a cumulative assignment in the methods course that was turned into their instructors but made accessible to me for analysis purposes. The course was the second of two required mathematics content courses for elementary teachers and generally focused on geometry, measurement, and number theory. I designed identical Google forms for each course instructor where students could submit their autobiographies and survey question responses. Each instructor's form was only be visible to the instructor and myself. I designed the written assignments so that participants would be free in their description of their experiences without the influence of someone in the room with them or any time restraint for their responses. The follow-up interviews allowed some students to expand and refine written responses that already expressed some of their attitudes and beliefs. I present a brief introduction to each interviewee below.

The Questionnaire. Prior to writing their mathematics autobiographies, students completed the Google form that asked for identifying information, including their age, gender, year in school, and majors and minors of study. This questionnaire used click-to-select type responses with the option of “other” for less common answers allowing them to fill in the blank. Questionnaire prompts can be found in **APPENDIX A**.

Using Narratives in Mathematics Education. Because I sought to understand the experiences that were most salient to my participants, I had to consider how I might collect data that did not presuppose certain experiences (as in force-choice surveys or Likert scales) upon my participants. Typically, as reported above, scholars have used Likert scales for measuring teachers’ attitudes and beliefs about mathematics, but we cannot know for certain how participants interpret survey questions nor infer which items were most important to participants (Philipp, 2007).

For some time now, scholars have used narratives (e.g., mathematics autobiographies or stories) as a means for preservice and in-service teachers to talk and write about the mathematics experiences of their lives (e.g., Drake, 2006; Ellsworth & Buss, 2000; McCulloch, Marshall, DeCuir-Gunby, & Caldwell, 2013; Stoehr, 2017). Drake (2006) elicited stories from elementary teachers in order to gain insight into the turning points in their feelings about mathematics. Six of the twenty teachers in her study shared turning point experiences, with all of them happening after their K-12 mathematics experiences. McCulloch and colleagues (2013) found that relationships with other people (e.g., teachers, family) were most impactful on the mathematics experiences of their elementary teachers, especially the amount of support they received from others.

The use of narratives can also allow researchers insight into how different constructs (e.g., attitudes and beliefs) are connected to one another (Drake, 2006; Zan & Di Martino, 2007). Zan and Di Martino (2007) found that students in their study consistently wrote statements of “I can/can't do mathematics" alongside statements of liking or disliking mathematics. They also noted those two statements were often tied to statements about how students viewed mathematics (e.g., I dislike mathematics because I can't do it because mathematics is a bunch of rules to memorize.). Hence, they claimed a relationship between three constructs – the emotions one feels about mathematics (either positive or negative), the beliefs one has about what mathematics is, and perceived mathematical competence – calling the relationship among the three "attitude toward mathematics," though it is more closely related to McLeod's (1992) term "affect" than my definition of attitudes.

The narratives I utilized (described in detail in the next two sections) allowed my participants to write about and interpret their own experiences, both positive and negative, in their own words, giving them complete freedom to choose which experiences they choose to relate and how they remember them. Their stories were written at a certain point in time, and hence may not accurately represent the actual events of their lives prior to that point in time. That said, the meaning and impact of the events about which they wrote were arguably no less important to them. As stated earlier, research using various surveys and scales has often reported the prevalence of negative attitudes and on the beliefs of elementary teachers and PSTs, but those studies have been silent as to the events that brought about those attitudes and beliefs. Narratives gave me the opportunity to learn about when and what events occurred that shaped the attitudes and beliefs of my participants (LoPresto & Drake, 2005).

The Autobiography. The Mathematics Autobiography, given on the first day of the course, asked students to write a 1-2 page autobiography titled "Me and Mathematics: My relationship with Mathematics until now" (Zan & Di Martino, 2007), and was due one week after it was assigned. The prompt students responded to can be found in **APPENDIX B**. The students composed their responses on a word processing program before uploading their autobiographies into the Google form. They had a full week to edit, add, or re-write the essay before submitting it.

The purpose for the autobiography was to solicit a story from all PSTs about their experiences with mathematics throughout their lifetime without the use of specific, guiding prompts. In their responses, students were free to present what was most salient and memorable in the formation of their relationship with mathematics over time. This essay was also an attempt to gather data relative to research question 4, as I specifically asked them to include major turning points—though I did not attempt to clarify or define that terms.

The Survey. The second round of the writing assignment posed ten questions designed to address each of the first three research questions in some way. I expected that students would focus more of their writing in the first-round autobiographies on their attitudes, so I provided prompts that I hoped would also get at their beliefs about mathematics. They are listed in Table 3.1 below.

Table 3.1

Survey Questions from 2nd Round of Writing Assignment

1	*How I feel about mathematics is…* 1 2 3 4 5 Strongly Dislike ○ ○ ○ ○ ○ Strongly Like
2	*I feel that way about mathematics because…*
3	*How much mathematics did you take in school before entering college? Do you think it's necessary for everyone to take all the mathematics you did in school? Why or why not?*
4	*Why do you think some students feel differently about mathematics than you?*
5	*Do you think your feelings about mathematics have more to do with mathematics just being mathematics or with your experiences in school mathematics?*
6	*What do you think mathematics is all about?*
7	*How do you see mathematics as different from other school subjects you like or dislike?*

Table 3.1 (cont'd)

8	*What kinds of mathematics do you do or have you done outside of school?*
9	*What do you see as the most important characteristics of being able to do mathematics well?*
10	*Do you think your beliefs about mathematics align with or differ from your parents' beliefs about mathematics?*

Questions 1-5 were designed to gain a better understanding of participants' attitudes and experiences they may have seen as important in the formation of those attitudes. Question 1 was important to my study, not only for sorting my participants into attitude groups, but also so I could speak to existing mathematics attitudes literature, much of which has used Likert scales to measure attitudes toward mathematics. Question 2 was intended to ….. It proved very useful in understanding what experiences participants recalled as most salient to the formation of their attitudes since they were asked to only write one or two sentences and hence picked only one or two things to say in their responses. Question 3-5 were not utilized as much in this study due to the vast amount of attitude data provided by the essays, survey questions 1 and 2, and later for the sub-sample, the interviews. These questions, however, may prove useful in a future study but they did not consistently produce useful data for answering this study's research questions. Questions 6-10 were intended to draw out my participants' beliefs about mathematics. Questions 6 and 7 proved most useful, as I found most participants wrote about issues other than beliefs or were not specific about their own beliefs for questions 8-10. Also, questions 8-10 were intended to draw out more of how their beliefs may have been formed, but they proved not as useful for that purpose as I had hoped. Like questions 3-5, 8-10 could prove useful in a future study under a different set of research questions.

The survey was assigned by the instructors on the day the first round was due. Students were provided a link to the Google form containing survey questions, and they submitted it to their instructor and myself when they had finished responding.

Interviews. Interviews started two months after the completion of the autobiographies and surveys and ran for 9 weeks. The interviews lasted between 30 minutes and an hour, consisted of two parts, and were all completed by the author in a one-on-one setting using Zoom video conferencing technology. In the first part, participants reviewed their autobiographies and highlighted the experiences they described as most impactful on their attitudes in order to build an "Attitude Graph." In the second part, I asked follow-up questions based on the responses to their prompts. The empty Attitude Graph can be found in **APPENDIX C** and the interview protocol can be found in **APPENDIX D**. In the Attitude Graph activity (adapted from Smith & Star, 2007 and Smith, Levin, Bae, Satyam, & Voogt, 2017), participants opened a Google doc where they saw the blank graph. The x-axis represented time over the course of K-12 and the y-axis represented attitude. Students filling their graphs could drag and place a red dot to "plot" their attitude at any chosen time. Participants not only plotted their attitudes toward mathematics over time on the graph, but they also annotated each point with a textbox describing the reason for their attitude rating at that point. Because I had access to their autobiographies for context, I asked the participants to summarize experiences in the text boxes if they referenced one of their highlighted statements from the autobiographies in order to save the graph from getting too cluttered. If the participant added something new that was not part of their autobiography, I asked them to provide more detail in the text box.

While I used all of the seven questions in the interview protocol, which focused on gaining some general information about my participants, clarifying and understanding their attitude graphs, and exploring their beliefs and favorite teachers, I also crafted specific questions for each participant based on their survey responses. For instance, I asked each participant why they chose their numerical response to Survey Question 1 and whether they still felt that number was accurate. I also asked clarifying questions about their survey responses. For instance, one participant wrote in their survey that there are “those who are good at [mathematics] and understand it,” so I asked her whether she thought there were “mathematics people and non-mathematics people.” Each participant addressed between four and seven of such follow-up questions to their survey responses before I moved on to the final two prompts: (a) how mathematics fits with how the world works and (b) their favorite teachers.

Pilot Study. Four months before I began my data collection, I conducted a pilot study with four participants (all preservice elementary teachers) to test my data collection methods and to inform my analysis. The pilot study was conducted in two rounds. In the first, I gave two participants one week to complete the autobiography and then gave them five survey questions from a previous version of the proposal. From the results, I found the autobiography garnered the stories and experiences for which I had hoped, leading to its use in the actual study. I noticed the original five survey questions did not get at what I had hoped, so I conducted an interview with one of my two participants to test some questions that could be used for new prompts and to test the Attitude Graph.

The Attitude Graph in the pilot interview functioned productively, so that activity was not revised. I also used this interview to inform my survey questions in the study, those found in Table 3.1. I also used the pilot interview to help develop the interview protocol. In the second round of my pilot study, participants wrote an autobiography, answered the revised prompts, and I conducted one follow-up interview to test my new interview protocol and re-test the attitude graph. All of it went very well, and I became more confident that my data sources would allow me to answer my proposed research questions.

Interview Participants

Participant Selection. The process of selecting interview participants occurred in two rounds. In the first round, I first sorted all whole-group participants based on the numerical rating (1-5) students provided to the first survey question “How I feel about Mathematics is…,” where 1 represented “Strongly Dislike” and 5 represented “Strongly Like.” The distribution of participants who indicated their willingness to be interviewed, sorted by attitude rating level, is given in Table 3.2 below.

Table 3.2

Whole-group Participants Willing to be Interviewed

Attitude Rating Level	Total Number of Participants	Number of Willing Participants
5	14	9
4	40	28
3	42	30
2	15	12
1	1	1

My initial goal was to reach out to an equal number of participants from each category 1, 2, 4, and 5 – hence focusing on their “like” and “dislike” of mathematics. With only one potential “strong disliker” available, I sought interviews with three participants from each of the 5s and 4s, five from the 2s, and then the one from the 1s category. My committee members also suggested it would be important to include the 3s (or “neutrals”) as well to get a complete picture, so I sought three more participants from the group of 3s, to give me 6 participants on the “like” side of the spectrum, 6 on the “dislike,” and 3 in the middle.

The one participant with a rating of “1” was an easy choice; she was the only participant to report a strong dislike for mathematics of the 112 participants in the whole group. She responded “yes” to my interview request and was interviewed. For the “dislikers” (2 response), I had initially sorted them into groups based on their experiences and autobiographies, but despite my efforts to choose amongst the twelve possible candidates, I ended up reaching out to all of them in time and secured only four interviews.

To choose in the remaining categories, I first looked at the surveys to get a snapshot of their reasons for their attitude ratings and their answers to the questions that focused on beliefs about mathematics. I sought diversity based on how they experienced and viewed mathematics. Some of the survey responses within groups were quite similar, so I opted to read the autobiographies of those who were similar to see if any stories warranted further exploration or if I could eliminate participants based on the thoroughness of their descriptions in their autobiographies. I ended up reading all of the autobiographies from all three remaining attitude groups, and I applied a set of sorting codes to each participant based on what their experiences seemed to be. Those codes can be seen in Table 3.3.

Table 3.3

Sorting Codes Used in the Selection of Interview Participants

Codes	**Description**
Always Positive (AP)	Seems to love mathematics, always have enjoyed it, great teachers, etc.
Almost Always Negative (AAN)	Seems to recount mostly negative experiences, but a few positive mixed in.
Almost Always Positive (AAP)	Seems to recount mostly positive experiences, but a few negative mixed in.
Unexpected (U)	Rating doesn’t seem to match autobiography.
Roller-coaster, ending up (RCU)	Relationship up and down throughout, ending positive
Roller-coaster, ending down (RCD)	Relationship up and down throughout, ending negative
Teacher Influenced (TI)	Teacher(s) made big impact on improved or positive/negative attitude
Peer Influenced (PI)	Peers influenced feelings about mathematics
Self-Influenced (SI)	Sites personal reasons (liking the challenge, working hard, confidence) as reason for liking it or not at times

Table 3.3 (cont'd)

Codes	Description
Mathematics-driven (MD)	Cites what they like about mathematics or beliefs about mathematics as main reason for liking it (e.g., Problem solving, puzzle, one answer)
Content-dependent (CD)	Cites liking mathematics depends on content being covered

From the "strongly like" group (responses of 5), I selected one participant because her rating did not seem to match her story. Despite giving a 5 rating on the survey, she reported an "almost always negative" relationship with mathematics. Since the two most common codes given to the strongly like group from Table 3.3 were "Always Positive" and "Roller-coaster, ending up," I reached out to two participants from each of those categories. Two declined or not did not respond to my interview invitation (including the only male participant who had indicated a willingness to be interviewed) but one from each category agreed to interviews.

From the "like" group (responses of 4), I eliminated one participant in her 30s because I wanted participants with more recent K-12 experiences, and I eliminated participants whose autobiographies were particularly descriptive and required less follow-up for more information. I chose one participant who I coded into the Roller-Coaster category because she mentioned liking mathematics at first, then disliking it for middle and high school with no justification for liking it again. I wanted to know what experiences changed her attitude. Since the top two categories from Table 3.3 for the like group were "Almost-always positive" and "Teacher Influence," I sought interviews from participants in each category. Like the strongly like group, the first participants contacted did not respond or declined interview. I eventually settled on one who had a unique belief-like statement (saying "Mathematics is different for everyone") and the other who was more detailed in her autobiography about her elementary experiences but wrote little about her time afterward.

For the “neutral” group (responses of 3), I likewise eliminated participants with detailed autobiographies and made my selection from the code assignments above. Many of the participants reported roller-coaster experiences, so I opted to choose one from “roller-coaster, ending up,” one from “roller-coaster, ending down,” and after a number of participants did not respond to my requests, I was able to find one from each roller-coaster category. My last participant was chosen based on her particularly interesting story where she seemed to describe a continually worsening experience with mathematics, so I was curious about her rating choice of 3 for what seemed to be a progressively more negative relationship with mathematics.

In the end, then, I ended up with fourteen interview participants in total, divided among the attitude ratings groups shown below in Table 3.4.

Table 3.4

Number of Interview Participants within each Attitude Rating Level

Attitude Rating Level	Number of Interview Participants
5	3
4	3
3	3
2	4
1	1

Participant Description. Here I give very brief descriptions of the fourteen participants who were selected for interviews. They are based mostly on the descriptive data they provided in their surveys with some details they provided in the beginning of their interviews. I provide this to give a picture of each participant beyond their number and attitude rating. I hope to show that while they may have fallen into similar categories of like or dislike, they are unique individuals with different backgrounds and stories, as the results will further indicate later. All fourteen participants identified as white females, so that identifying information will be left out of their individual descriptions. While I recognize the narrow range of diversity amongst my interviewees, this sample is largely representative demographically of the whole population of preservice elementary teachers at the institution from which they were recruited. All were between the ages eighteen and twenty at the time of the interview.

Participant 1 was a junior majoring in Special Education. She attended public schools in a suburb outside a large metropolitan area and spent a year attending her local community college before transferring to the university. She described her K-12 school experiences as “nothing but good times,” despite forming a very negative relationship with mathematics over time. She was the only participant in the whole group to say she “strongly disliked” mathematics on her survey.

Participant 2 was a sophomore majoring in Elementary Education with focus in Mathematics and a minor in French. She grew up in a university town and attended public schools there; her father was one of her elementary teachers. She described school as always feeling fun to her; it felt like being a part of a family. She reported a rollercoaster relationship with mathematics, often beginning school transitions (elementary, middle, high) with negative feelings toward mathematics before finding them improve over time in each school.

Participant 3 was a sophomore majoring in Special Education with a minor in Spanish. She attended medium-sized, suburban public schools, and reported enjoying the experience of school but never felt very connected to her peers in school. She described herself as being “mathematics-anxious” throughout her time in K-12, but in college experienced a 180-degree turn in her relationship with mathematics and now reports “strongly liking” it.

Participant 4 was a sophomore who attended a public school in what she called a medium-sized suburban town. She was majoring in Elementary Education with a Mathematics concentration. Though she went through a period of her life where she felt she got caught up in what she called “the stigma” of disliking mathematics in middle school, she reported mostly positive, successful experiences with mathematics overall.

Participant 5 was a freshman majoring in Special Education with a focus in Mathematics. She attended public schools through middle school but switched to a Catholic high school in ninth grade. While she reported always liking mathematics as a subject, she reported “hating” her experience with the Common Core Mathematics Standards in middle school. She was relieved when she found mathematics to be taught at the private, Catholic high school more in the direct-instruction way that she had loved in elementary school.

Participant 6 was a sophomore from the East Coast who attended mid-sized, urban public schools from 2nd grade through high school. She was majoring in Elementary Education with dual foci in English as a Second Language and Language Arts. She reported really enjoying her experiences in her school community but had a negative experience with one mathematics teacher who would “scream and yell” at her students that soured her relationship with mathematics. She reported a number of ups and downs, but she carried the negative side-effects from that teacher, who she had twice, with her through the rest of her schooling.

Participant 7 was a sophomore majoring in Special Education with a focus in Language Arts. Her experiences in elementary school with ability grouping – namely, having her teacher split her class into “advanced” and “regular” sections – made her think she was not capable in mathematics and hence soured her attitude toward mathematics. For the most part, that attitude was only reinforced for the rest of her time in K-12 by her experiences with teachers and by low test scores.

Participant 8 was a sophomore majoring in Elementary Education with dual foci in Language Arts and Teaching English to Speakers of Other Languages (TESOL). She grew up in a very small, rural town where she said the social messages she received from her peers, teachers, and community were that “Girls aren’t good at mathematics. You’re a girl. You shouldn’t be good at mathematics.” That message was reinforced in her schooling, and so, despite her continued success and high grades in mathematics, she formed a negative relationship with it.

Participant 9 was a freshman majoring in Elementary Education with a Spanish concentration. She overcame many family moves and a number of negative experiences in her personal and school life to maintain a positive relationship with mathematics – except for calculus. She said that despite all of her positive experiences with mathematics, calculus left her hating mathematics, at least for a time, before her college experiences re-established a more positive attitude toward it once again.

Participant 10 was a sophomore majoring in Special Education with a focus on Communicative Sciences and Disorders. She attended mid-sized public schools in a mid-sized town, where teachers had the biggest impact on her relationship with mathematics. Her feelings tended to change with each teacher, and unfortunately, that left her with a mostly-negative feeling toward mathematics.

Participant 11 was a junior majoring in Elementary Education with an unspecified focus area of study. She grew up in a very small, rural town where for much of her early experiences with mathematics, she felt unchallenged and bored. Once she reached high school, she had some ups and downs in her relationship with mathematics –based on her experiences with teachers.

Participant 12 was a freshman majoring in Early Childhood Development with no other areas of concentration. She attended a large, urban school with huge class sizes, not enough desks, was largely “under-staffed,” and generally lacked the proper resources. Despite all that, she called it a “decent school” and would not trade her experiences there for anything. She had positive experiences throughout elementary and middle school before a downturn in high school that left her feeling nervous about mathematics.

Participant 13 was a freshman majoring in Elementary Education and had not yet declared a focus area of study. She grew up in a mid-sized midwestern city and attended a talented developmental elementary school before attending the standard public schools in middle and high school. She had some negative early experiences with mathematics and ended with more positive experiences, which were largely affected by her feeling of understanding and her experiences with her mathematics teachers.

Participant 14 was a sophomore majoring in Elementary Education with dual foci in Language Arts and TESOL. She attended public schools in the outskirts of a large city, calling her schools academically focused and competitive. She said that “there was a lot of pressure….to do well, especially in STEM classes, like mathematics and science, they were like, yeah, do good. Or else you’re stupid.” She reported both positive and negative experiences with mathematics, with most positive happening before middle school followed by mostly negative experiences.

Chapter 4: Data Analysis

In this chapter, I describe how I analyzed the data collected from the sources described in Chapter 3. I used qualitative methods to address my research questions, since I wanted to understand not only what attitudes and beliefs my participants held about mathematics, but also the genesis of those attitudes and beliefs. To analyze the essays, I used a paradigmatic-type narrative inquiry approach (Polkinghorne, 1995). In other words, I sought to understand how my participants interpreted their prior experiences with mathematics and developed categories of the experiences they saw as influential on their attitudes and beliefs about mathematics. In the sections that follow, I present my analysis process for answering each research question.

Research Question 1: Description of Attitudes

My first research question asked, *What is the overall landscape of attitudes toward mathematics amongst preservice elementary teachers?* My analysis sequentially addressed the whole-group participants and then the interview participants. For the whole group, I utilized data from the Survey Questions 1 and 2, and for the interview participants, I utilized data from all four sources – autobiographies, survey questions, attitude graphs, and interviews. Though I read all autobiographies for the whole group, my goal here was more of an overview for the large group, with the interview participants providing a more zoomed-in, detailed look at attitudes. Analyzing the entire sample of autobiographies would have been beyond the scope of this study, though still may be fruitful for future study.

Whole-Group Attitude Analysis. For the whole group, my analysis goal was to produce both an overview of the attitudes from their Likert scale responses to Survey Question 1 ("How I feel about mathematics is…") analysis of their responses to Survey Question 2 ("I feel that way because") for consistency with their numerical rating. As a reminder, I defined *attitudes about* *mathematics* as judgements about mathematics that reveal one's disposition toward it, and I set it up as synonymous with "feelings about" mathematics. Hence, responses to Survey Question 1, where participants chose a number from 1-5 corresponding to "strongly dislike," "dislike," "neutral," "like," and "strongly like," gave me an initial top-level view of their attitudes as well as helping me choose my interview participants. The responses to Survey Question 2 allowed me to explore some complexity about how they reported their overall attitude numerically. For instance, some participants rated above "dislike" on the attitude scale (3, 4, or 5) but listed only things they did not like about mathematics in their reason for their rating. When this seeming mismatch between their rating and their reasons for their rating emerged, I identified their attitude choice as not necessarily matching the reasoning for it. This was most common among the 3s; only a few 4s and 5s were identified. The "dislikers'" (1s and 2s) reasons expressed in their Survey Question 2 were consistent with their negative numerical ratings.

Interview Participant Attitude Analysis. My interview participants' stories were analyzed more deeply by including their autobiographies and interviews. I first transcribed all interviews using the online transcription resource, Temi.com, and I checked line by line with the audio and fixed any inaccuracies from the auto-transcription tool. I then sorted my participants by their Survey Question 1 attitude rating. Then, I read and analyzed their autobiographies and interview transcripts for *tone* using a process similar to Drake's (2000) coding. Following Drake, I assessed tone by comparing the number of positive qualifiers (e.g., like, love, joy, excitement) my interview participants used when talking or writing about mathematics versus negative qualifiers (e.g., hate, dislike, dread).

I also analyzed my interview participants' Attitude Graphs, where they depicted their attitude toward mathematics graphically by plotting points representing their feeling about mathematics over time. To address research question 1, I removed the descriptive text boxes where participants wrote their reasons for their attitudes at any given point, as my question focused on what their attitudes were, not how they came about. The attitude graphs were analyzed based on the shapes of their graphs (e.g., linear, up-and-down, parabolic) and the relationship between their attitude rating level from Survey Question 1 and where they plotted points on their graph. My purpose was to further decipher the consistency of their attitude ratings at a given point with the fluctuations of their attitudes over time. I wanted to know if they were deciding on their ratings based on how they felt at the moment of the survey or alternatively if they appears to average their feelings toward mathematics over time. I also analyzed the fourteen graphs as a group. I did so through looking at the shapes of their graphs in two directions: first by looking at the similarities and differences between the shapes of their graphs for the same attitude rating and then by grouping similarly-shaped graphs and looking at the consistency in their attitude ratings.

Research Question 3: Experiences' Effects on the Formation of Attitudes

While working to address to research question 1, I found it would make sense to continue working specifically on attitudes rather than switch to the beliefs-focused research question 2 and come back to attitudes later. Also, during the initial selection of my interview participants, I noticed participants in the whole group more-often wrote in their autobiographies and survey responses about experiences they recalled that informed their attitudes toward mathematics than they did about experiences related to their beliefs about mathematics. As a reminder, I considered statements related to their dispositions toward mathematics (e.g., like, dislike, love, hate) as an attitude and statements describing what they hold to be true about mathematics –

whether in relationship to their experiences or generally (e.g., mathematics is fun, mathematics is about problem solving) as beliefs.

Hence, in this section I focus on my analysis process for addressing my third research question: *What experiences do preservice elementary teachers attribute to having shaped their attitudes and beliefs about mathematics?* I will specifically address how I analyzed the data for experiences related to attitudes, and I will return to how I analyzed participants' beliefs about mathematics in a later section. As with research question 1, I will begin with the whole-group analysis approach before describing the process for my interviewees.

Whole-Group Experiences and Attitude Analysis. I began my analysis for research question 3 by first taking all 112 whole-group participant responses and sorting them by their attitude rating response to Survey Question 1. Then, I began analysis of each of their responses to Survey Question 2, where participants explained their feelings about mathematics by writing a brief response to "I feel that way because," by sorting their responses and looking for common themes within each rating level. This iterative approach initially produced twelve categories that I used to code 168 total statements that addressed formative experiences. I further coded each response as "positive," "negative," or "neutral" based on the tone of the participant response. Coding for tone was a relatively easy task for those who indicated disliking or liking mathematics, as their numerical rating frequently helped to clarify meaning, neutral responders posed more of a challenge since they often gave reasons that were both positive and negative in some way. I coded statements as "neutral" when either participants included a combination of one positive and one negative statement or their statement did not indicate either positive or negative disposition.

Following my initial development of the coding scheme and coding of the responses, I enlisted the help of another mathematics education graduate student to review my coding– including the tone ratings – and make note of any suggestions he would have for changes to either the code descriptions or the codes I assigned to the participant responses. The graduate student I engaged is one I have been working with on a research project for two years and had experience with qualitative coding both on the project and his own small research projects and his practicum study. He was also an efficient worker and not afraid to give critical, thoughtful feedback. Out of the 168 coded responses, my colleague questioned my coding in sixteen instances. We then met to discuss and resolve the differences, after which eight changes were made and eight codes remained as they were, achieving 100% agreement. Of the eight changes, three of them involved shifting the statement from one coding category to another, and five were resolved by splitting a statement into two or more parts and coding each separately. Hence, 97% of my initial codes ended up unchanged after we came to an agreement, and no changes were suggested or made to the categories themselves or to the tones I had assigned. After achieving this consensus, there were 175 total coded instances of experiential bases for students' attitudes toward mathematics.

After analyzing the results from Survey Question 2, I analyzed their autobiographies for experiences participants wrote about as impactful on their attitudes. With so many whole-group participants (n=112), I could not feasibly code all of the data, so I took a random sample of roughly half the whole-group autobiographies to analyze. Utilizing an online random number generator, my sample included one "strongly dislike" participant (from N = 1), eight "dislike" participants (from N = 15), 21 "neutral" participants (from N = 42), twenty "like" participants (from N = 40), and seven "strongly like" participants (from N = 14). Because I did not want to make assumptions about how their expressions of their experiences might have affected their attitudes, I analyzed all statements that were attached to a positive or negative assessment of their feelings toward mathematics. I highlighted each statement they mentioned related to mathematics in their autobiography and coded them using the coding scheme developed during my analysis of Survey Question 2, while also developing some new categories and codes. All experiential statements were, as before, coded for their tone, and since I only chose experiences attached to positive and negative assessments of their feelings about mathematics, there were no neutral tones in this analysis. Any statement that carried both a positive and negative tone within a category was split into two statements, each with its own positive or negative tone. This analysis resulted in 501 statements coded into sixteen categories.

Interview Participant Experiences and Attitude Analysis. Each interview began with the participant re-reading their autobiography and annotating it by highlighting the moments she found affected her feelings about mathematics. Participants were also instructed they might later include these moments on their attitude graphs. I carried out a similar analysis to the whole-group autobiography analysis above, but I used only the events or experiences that the participants highlighted as impactful on their attitudes. I did this so I did not determine the events most salient to my participants. Rather, since they did the highlighting, I had confidence that I analyzed the most important events as they recalled them. I used the same codes and subcodes established previously, and I created new codes as necessary. Since many of the experiences participants highlighted were included on their attitude graphs, I was able to confirm my assignment of positive and negative codes to most of them based on their location in the y-direction of the graph. Those statements not located on the attitude graphs were assigned positive and negative codes based on the context of the autobiographies, as they were before in the whole-group analysis above.

In this part of the analysis, I used their graphs to gain information about not only what events were most important to participants, but also as a representation of how their attitude changed relative to when they happened (i.e., elementary, middle, high school, or college). I also could see just how influential they perceived those events to be (e.g., drastic changes from positive to negative, minor dips or raises in attitude). I took a narrative approach in my analysis and subsequent written report in the dissertation, as the graphs tell a story of my participants' experiences both in their shape and in the annotations made at each data point.

Research Question 4: Turning Points in Participants' Attitudes Toward Mathematics

As part of my analysis on experiences affecting attitudes, I made note of any turning points participants described with respect to their attitudes toward mathematics. Thus, this section describes the analysis process that addressed for my fourth research question: *What types of experiences tend to be turning points in the mathematics attitudes and beliefs of preservice elementary teachers?* As a reminder, *turning points* in this analysis were any experiences or events that brought about significant change in attitude toward mathematics. While I asked participants to include turning points in the autobiography activity, very few called events a "turning point" in their writing or signified in some way that certain events were more significant than others. Hence, with the permission and encouragement from my committee, I focused my analysis for turning points only for the interview participants and only on attitudes since I specifically asked my interviewees to describe which points on their attitude graphs, if any, they considered to be turning points in their relationship with mathematics. Due to some technological issues with internet connection, I was not able to ask the turning point question to one participant, but she did respond to an email inquiry I made after the interview and hence I was still able to obtain the turning point data for her.

Once I identified turning points from the transcripts of their interviews, I coded them qualitatively using categories and descriptions adapted from those used by McCulloch et al. (2013). Table 4.1 gives the categories and descriptions with which I began. Not all of my participants fit into exactly one category or any category at all, which resulted in creating a new category (Snowballing, see Table 7.10 for its description) for some participants and placing one participant into multiple categories (Snowballing for part of her history followed by Roller Coaster). I also included coding categories where there was no turning point (Smooth Track, Consistently Frustrated), though no participants reported experiences that fit into these categories.

Table 4.1

Framework for Characterizing Participants' Turning Points in their Attitudes

Experience Type	**Description**
Smooth Track	PSTs had no negative mathematics experiences
Minor Setback	PSTs experienced one or two negative mathematics experiences, but they were not detrimental to their overall attitude
Roller Coaster	PSTs have both positive and negative experiences throughout schooling
Consistently Frustrated	PSTs have primarily negative early experiences and accepted them as foreshadowing a lifelong mathematics weakness
Positive Turning Point	PSTs have strongly negative memories of mathematics up until a particular point (turning point), in which one specific positive experience resulted in a more positive attitude toward mathematics or a realization that it is possible to succeed at and enjoy mathematics

Table 4.1 (cont'd)

Experience Type	Description
Negative Turning Point	PSTs have positive memories of mathematics up until a particular point (a turning point) in which one specific experience resulted in a more negative attitude toward mathematics

(adapted from McCulloch et al., 2013, p. 383)

The attitude graphs also provided a visual representation of turning points, so I included that data source in my narrative descriptions of the turning points in their attitudes toward mathematics. The graphs also assisted in justifying some of the choices for how the participants' turning points were classified.

Research Question 2: Beliefs about Mathematics

In this section, I present the analysis process I used to address my second research question: *What beliefs do preservice elementary teachers with positive and negative attitudes hold about the nature of mathematics?* As a reminder, I considered beliefs statements to be those describing things they hold to be true about mathematics. While I initially wrote this question with the intention of splitting the group into "likers" and "dislikers," I opted to also include my neutral participants since they were not necessarily be neutral in their expressions of their feelings toward mathematics and hence would likely provide valuable data. The data sources used in this analysis were Survey Questions 2, 6, and 7, the sample of the mathematics autobiographies described above, and interview participants' interview transcripts and autobiographies. I analyzed responses to Survey Question 2 because in my prior analysis of attitudes, some beliefs statements surfaced in participants' responses. Survey Question 6 was designed to bring about beliefs in the first place and was effective in doing so. After reading through the rest of the survey question responses, responses to Survey Question 7 was another particularly promising site for beliefs statements, as students often stated beliefs about mathematics while comparing it to other subjects. I will address how I developed categories of different types of beliefs about mathematics from the data, and as before, begin with the whole-group analysis approach before describing how I analyzed the interview participants' data sources.

Whole-Group Beliefs Analysis. As with my analysis on attitudes, I began by taking all 112 whole-group participant survey responses and autobiographies and sorting them by their Survey Question 1 numerical attitude rating. Then, I began my beliefs analysis with Survey Question 6 ("What do you think mathematics is all about?") by taking their responses and using a bottom-up approach to develop categories of beliefs about mathematics. I looked for both beliefs related to the nature of mathematics (e.g., "Mathematics is a set of rules we need to memorize" and "mathematics is about solving equations") and beliefs grounded in one's personal experiences but still expressing general truths about the subject (e.g., "Mathematics is uninteresting," "mathematics is fun"). An iterative approach initially produced eighteen beliefs categories containing 180 statements. Some participants expressed multiple beliefs in their Survey Question 6 responses, and some beliefs statements fit with multiple categories.

A similar analysis of Survey Question 7 ("How do you see mathematics as different from other school subjects you like or dislike?") produced 93 more beliefs statements and six new beliefs categories. After sorting the 273 total belief statements into the 24 categories, I once again engaged my graduate student colleague in mathematics education to review my category assignments and make suggestions for any changes to the category descriptions. Out of the 273 coded beliefs statements, my colleague identified 21 of them as requiring review or possible change. After meeting together, we agreed to seventeen changes. Thirteen codes were found to apply to secondary categories in addition to those they were currently assigned, four were moved to completely different categories, and one was deleted from its category, resulting in 192 total beliefs categorized from the Survey Question 6 responses and 95 from Survey Question 7. He gave no suggestions for changing the category descriptions.

Following the analysis of the responses to Survey Questions 6 and 7, I went back to Survey Question 2, which asked participants to give a reason for their Survey Question 1 attitude rating. I identified the beliefs statements from my previous analysis of the Survey Question 2 attitude responses and assigned them to the 24 beliefs categories. Two new categories emerged from this work. I also read the same random sample of autobiographies I had used in my prior attitudes analysis, which produced 26 belief statements written by nineteen participants out of the 57 whole-group participant sample. Three new categories of beliefs emerged from this analysis, bringing the total to 29 beliefs categories between all whole-group data samples.

Interview Participant Beliefs Analysis. Last, I analyzed my interview participants' interview transcripts for statements that expressed beliefs about mathematics. Beliefs statements both included those spontaneously stated and those that emerged in responses to my questions. 60 total beliefs statements were found in the transcripts and assigned to the 29 beliefs categories from before, with no new categories emerging from the data.

Chapter 5: A Portrait of Pre-Service Teachers' Attitudes

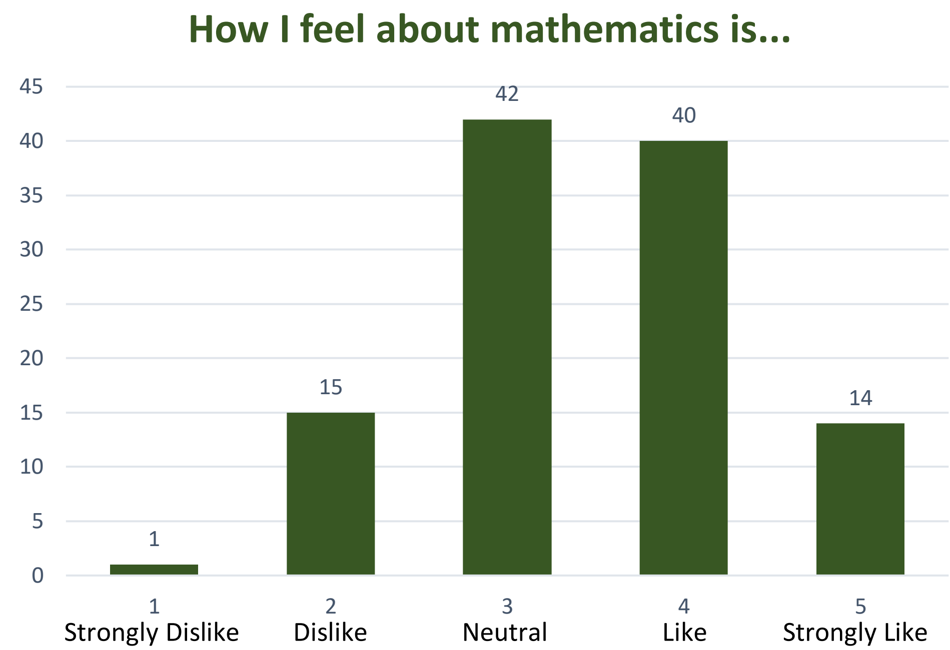
In this chapter, I address my first research question, *What is the overall landscape of attitudes toward mathematics amongst preservice elementary teachers?* I begin with results from my analysis of the whole-group participant responses to Survey Question 1 – their numerical self-assessment of their attitude toward mathematics – and Survey Question 2 where I assessed the agreement between their numerical ratings and their main reasons for them. These results give a broad overview of participants' attitudes, but not a deep or clear one. Then, I provide a more detailed view of PSTs' attitudes from my analysis of the interview participants' Survey Question 1 and 2 responses, mathematics autobiographies, interview transcripts, and attitude graphs. Recall that I used their attitude graphs to understand how their attitudes changed over time, and I analyzed their autobiographies and interviews for tone to test further for agreement between their self-assigned numerical rating and how positive or negative they were in presenting their histories with mathematics.

Whole-Group Survey Results

My first survey question was a 5-point Likert prompt "How I feel about mathematics is…" that asked participants to select a numerical response from 1 to 5 corresponding to their "strongly dislike," "dislike," "neutral," "like," and "strongly like" respectively. A top-level view of the results to the survey question can be found in Figure 5.1 below. The literature summarized previously indicated that elementary preservice teachers have been found to generally dislike mathematics and experience mathematics-anxiety. The results of my survey indicate that, for this particular group of PSTs, far more like (n=54) mathematics than dislike (n=16) it.

Figure 5.1

Bar graph displaying the results from Survey Question 1.



I argued previously that forced-choice or Likert-scale survey responses may not provide enough information about people's attitudes toward mathematics, and I found that this surface-level view of the survey data indeed failed to paint a complete portrait of how this large group of PSTs actually felt about mathematics. As I read their responses to Survey Question 2, "I feel that way because," I noticed some disparity between their Likert-scale survey responses and their open-ended descriptions of why they felt that way (see Table 5.1). All of the responses that did not match their numerical ratings were found in the "Strongly Like", "Like", and "Neutral" ratings of 5, 4, and 3, respectively, and the majority were neutrals. For the likers (ratings 4 and 5), the responses did not match if the PSTs (a) did not give explicit mention of liking mathematics, while also in turn pointing to a more negative experience with mathematics (b) indicated their feelings as only recently developed (and mentioning prior dislike) or (c) indicated their rating number may not hold for all aspects of mathematics or school mathematics (e.g., mathematical subject, homework quantity). For neutrals, non-matching responses either (a) indicated only negative experiences with mathematics (b) gave explicit mention that they dislike mathematics or some trait of mathematics or (c) focused only on their future teaching mathematics not on past experiences with mathematics. All of those with dislike responses (ratings 1 and 2) consistently presented a dislike or strong dislike of mathematics in Survey Question 2. All Survey Question 2 responses for my participants with mismatched ratings and reasonings can be found in **APPENDIX E**.

Table 5.1

Participants' consistency on Survey Question 1 and 2 responses.

	Strongly Dislike	Dislike	Neutral	Like	Strongly Like
Total	1	15	42	40	14
Non-Matches	0	0	10	3	1
Matches	1	15	31	37	13

The one non-matching "strongly like" responder indicated that her K–12 experiences would have put her at a dislike or neutral rating, but it was her experiences in her elementary mathematics content courses that boosted her to strongly like. This indicates a strong "timing of survey" effect, the well-documented phenomenon of recency in educational psychology and ever-present possibility to surface in survey results (e.g., Krosnick, Judd & Wittenbrink, 2018). Had the survey been given right after her high school experiences or just before entering her elementary content courses, she could well have been categorized as disliking mathematics, yet now indicated a strong like for the subject. I also interviewed this participant, and she indicated there and in her autobiography (detailed later in this chapter) that she was mathematics-anxious all through elementary, middle, and high school.

Participants who gave "like" ratings and gave inconsistent explanations indicated that mathematics has too much homework, gives them anxiety or nervousness, and that their rating was dependent upon the subject matter (e.g., algebra, geometry). While the first two reasons seem understandable due to their negative tones toward mathematics (or school mathematics) despite a rating indicating liking mathematics generally, the third indicated a fluctuating experience and thus could not be labeled as how she feels about mathematics generally. Rather, her feelings were course- or subject-dependent. She preferred algebra to geometry, but geometry to calculus.

Inconsistent responders with neutral ratings (N = 10 of the total 14) were more interesting in their reasoning. All of them indicated some level of dislike for mathematics in their reasoning for their rating with the complete absence of any positive content. I found it interesting that there were no reasons given in the other direction, i.e., no participant gave a reason for liking mathematics without also mentioning something they disliked about it. One possible reason is that these participants filled out their survey rating in their course, and because their course instructor would see that rating they did not feel comfortable rating lower than neutral. Another might be that they generally liked school, and so while mathematics was "less than" their favorite subjects for the reasons they indicate, they did not dislike it. Or perhaps they felt those aspects brought them down from the realm of like, but not enough to the realm of dislike (this seems more likely). Regardless of the reasons (which will be explored further in Chapter 7), these results further illustrate the variation in participants' meaning of a rating of "neutral."

Interview Participant Attitudes

As indicated in Chapter 3, I chose my interview participants to be relatively evenly distributed across the attitude scale. I selected three participants each who indicated a survey rating of 3, 4, or 5, four who indicated a rating of 2, and one at a rating of 1. As a reminder, only one participant in the study to put a strongly dislike rating which is why I made my dislike group

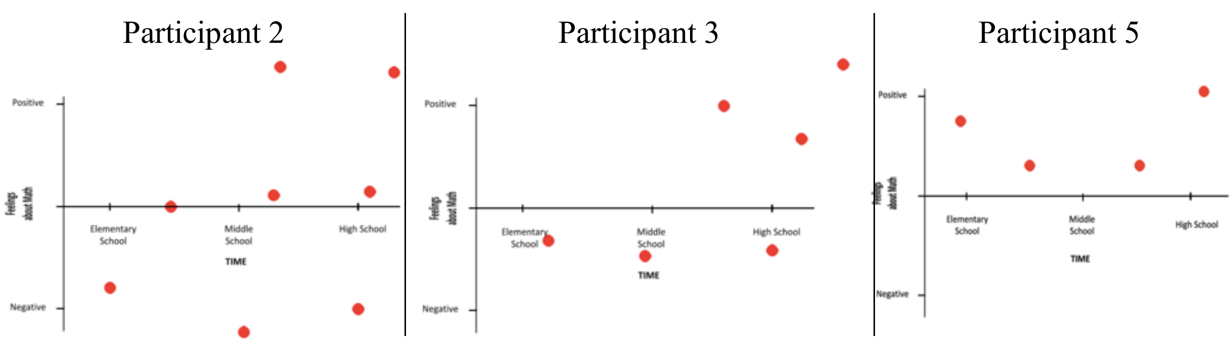
– rating 2 – larger than the others. Though their ratings were distributed across the attitude scale, the graphs they created during their interviews paint do not easily align with those ratings, often showing fluctuating views of attitude toward mathematics. The variability in their attitudes over time suggest their ratings may have carried different meanings for each participant. For instance, some may have chosen a number that represents an “average” of their feelings over the course of their lives while others rated based on recent events (e.g., feeling really good having just left a good mathematics class, a recent set of courses improving or lowering their attitude).

Below, I report results from each grouping, from strongly like to strongly dislike, in more depth. Within each grouping, I will draw on the interview participants’ attitude graphs (with annotations removed) to provide a visual of their changing attitudes over time.

Strongly Like. Figure 5.2 shows the attitude graphs for the three participants who indicated “strongly liking” mathematics in their Q1 survey response.

Figure 5.2

Attitude graphs for participants indicating “strongly liking” mathematics (rating level 5).



The graphs show that those who had strong positive attitudes toward mathematics at the time of the survey indicated quite a bit of variability in how they felt about mathematics at various points during their time in school. Participants 2 and 3 indicated a rollercoaster relationship with mathematics over time and located their past feelings frequently in negative territory; only Participant 5 had a generally positive relationship with mathematics throughout.

The autobiographies and interviews likewise showed similar variability in the participants' tone, or the positive or negative qualifiers they used (e.g., love, hate), when discussing mathematics, though two out of the three participants had an expectedly positive tone.

Participant 2's graph shows an interesting trend. She began with a strongly negative attitude toward mathematics at the beginning of each school level (elementary, middle, high), but by the end of each interval of time she felt better or very good about mathematics. By the end of high school she felt so good about mathematics that she chose mathematics as her subject focus in her elementary education major. She said that she feels she can do mathematics "for hours and time doesn't seem to exist." She considered herself a mathematics-science kind of girl, and she especially enjoyed taking Calculus II and III at the college level. Between her interview and autobiography, she expressed an overall positive tone, with nine positive qualifiers versus only three negative.

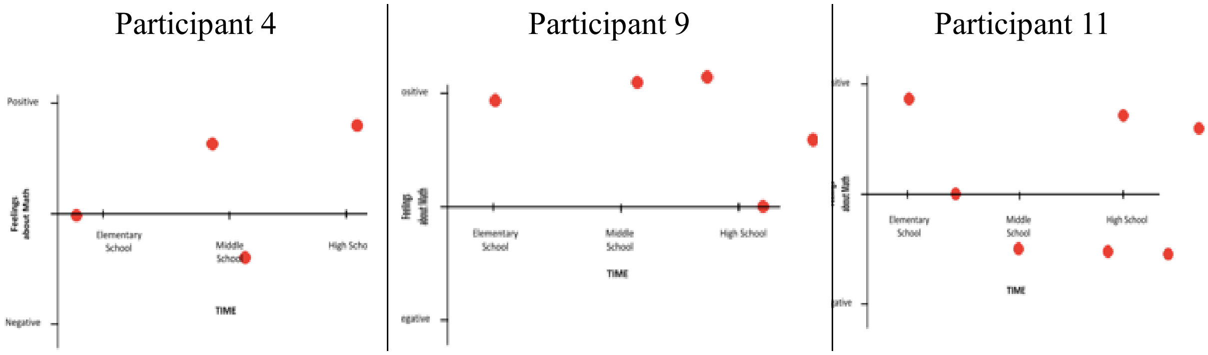
Participant 3, the only interview participant who was found inconsistent in the whole-group analysis, indicated in both the survey and the autobiography a consistent negative experience with mathematics, including hating mathematics at many points throughout her time in K-12 mathematics. Her tone was overall negative, with no positive qualifiers in her autobiography, and overall having eight negative qualifiers to seven positive. Though that seems like a small disparity, five of the seven positive qualifiers were about her recent college mathematics experiences, and all eight negative qualifiers were about her K-12 experiences with mathematics. The interview and tone findings revealed the effect of taking the survey recently, as she indicated her first-semester elementary content course as substantially shaping her attitude toward mathematics. She admitted, "I took it right after I left mathematics class, I was like, oh, I'm feeling pretty good." In both her survey responses and interview, she indicated that had she taken the survey directly after her K-12 experiences, she likely would have rated herself a 2 or 3.

Participant 5 was the only participant whose graph remained consistently above the x-axis. Her tone was likewise more positive than the others with eighteen positive qualifiers to only seven negative when discussing mathematics. Like Participant 2, she chose mathematics as her focus subject in her special education major. She especially liked finding "the right answer" to mathematics problems and the feeling of knowing she got it right. Her recent elementary content courses and calculus were her favorite mathematics courses, which likely influenced her rating of 5; the graph shows some dips happening during her experiences in K-12 school. Despite indicating some negative comments about mathematics, she said that though there were ups and downs in her relationship with mathematics, she always maintained a positive attitude, which her graph also indicates.

Like. Figure 5.3 shows the three graphs for those who indicated "liking" mathematics in their Q1 survey responses. Again, the graphs reveal quite a bit of variability in their recollected attitudes toward mathematics over time. The graphs indicate that Participants 4 and 9 remained mostly positive throughout their experiences, with only one "blip" in their attitudes each, and Participant 11 seemed to have a more rollercoaster relationship with mathematics. The autobiographies and interviews tell a more complex story, however, as will be described for each participant below. These participants' tone about mathematics was generally not as positive as those who rated "strongly like" above, and two participants had more of a neutral or negative tone overall.

Figure 5.3

Attitude graphs for participants indicating "liking" mathematics (rating level 4).



Participant 4 expressed the most positive tone of the three "likers," using ten positive qualifiers when talking about mathematics in her autobiography and interview while only using three negative qualifiers and calling her attitude "neutral" in elementary school. Her only instance of feeling dislike toward mathematics happened in middle school when she said she first felt a stigma about mathematics from her peers that mathematics "was awful and hard." Otherwise, she said that mathematics had always been very satisfying and gave her confidence. She said that taking the survey while struggling in her first few weeks of her first calculus class kept her at a rating of 4, and if she were to have taken the survey at another time, she would have put a 5 because of having later success in her calculus course.

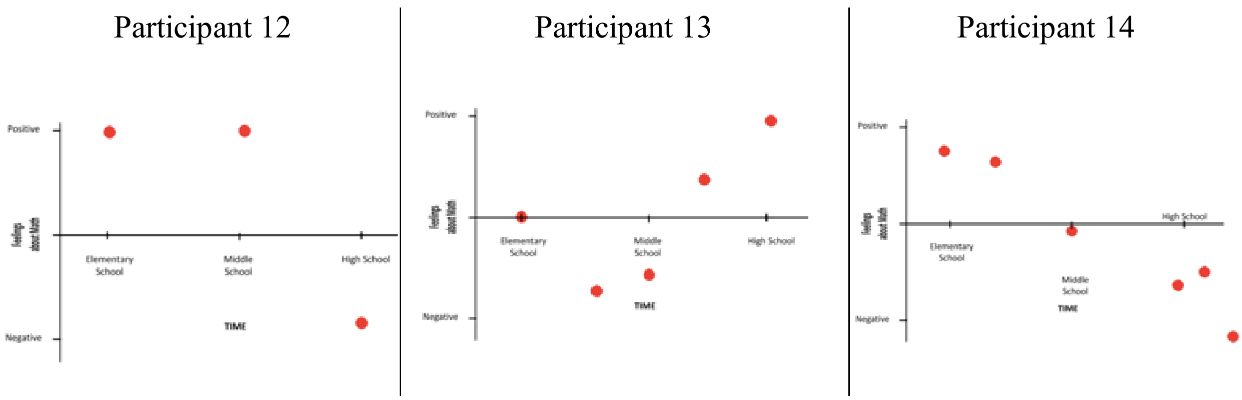
Participant 9 indicated in her survey that she liked all mathematics except for calculus, initially leading me to think that put her rating at like instead of strongly like. Her autobiography confirmed that thought, as though she had a mostly positive tone about mathematics throughout, she ended with a negative tone as she recounted her experiences with calculus. It was her final statement that ultimately prompted me to reach out to her for a follow-up interview when she said, "Long story short… I used to love mathematics and be good at it, but now I dread and avoid it. Yay me." Her follow-up interview also carried a negative tone, giving her more negative statements about mathematics (*n*=7) than positive (*n*=6) between her autobiography and interview. That said, the vast majority of her negative comments came about her experience with calculus during her senior year of high school. She did say in her interview that she still overall enjoyed doing mathematics, and she had been enjoying her experiences in her elementary mathematics content courses. This is another instance where the timing of the survey—in her second semester of elementary mathematics content courses as opposed to right after high school—certainly impacted her response choice.

Participant 11 expressed a more neutral tone about mathematics. She had the same quantity of positive qualifiers as negative qualifiers in both her interview and autobiography. In her autobiography she wrote “Overall, I’ve had a rollercoaster ride journey with mathematics. At times it was my favorite subject and others I didn’t enjoy it at all,” and her graph was a visual confirmation of her description. Like Participant 9, Participant 11 would have selected a different rating if the survey was taking directly after high school. She wrote in her autobiography that she had “the worst teacher ever known to man” for her senior-year calculus class. Also, like Participant 9, she indicated in her interview that her recent experiences in her elementary content courses are why she now has a positive attitude toward mathematics again.

Neutral. Unlike the previous two groups of participants, those who indicated a neutral attitude (rating of 3) on survey Q1 did not end their attitude graph data points (see Figure 5.4) at locations consistent with their final rating (on or near the x-axis). Two participants indicated a recent very negative attitude toward mathematics whereas one indicated a recent positive attitude. Their survey responses indicated that they either chose 3 as “an average” of their experiences or because their attitude varied depending on the subject matter or some other condition relative to the mathematics (e.g., when there are too many steps). Hence, these three participants did not show recency effects and perhaps looked at the rating more holistically than those above. The overall tone from the three participants' autobiographies and interviews was relatively neutral, outside of Participant 12's autobiography, which carried a more negative tone.

Figure 5.4

Attitude graphs for participants indicating feeling "neutral" toward mathematics (rating level 3).



Though Participant 12 reported a negative tone in her autobiography as she recounted her experiences in high school mathematics, her interview tone was neutral, with five positive and five negative qualifiers when discussing mathematics. Ultimately, she said she chose a rating of 3 based on her positive experiences while in elementary school, middle school, and her first elementary mathematics content course and negative experiences while in high school. She said that her experiences in high school were ultimately not enough to get her to dislike mathematics itself because those were the only years she had such negative experiences with it, but they were enough to bring her down from liking mathematics. Note that though she ended her graph with her negative experiences in high school, she discussed her positive elementary mathematics content course beyond that as a positive experience.

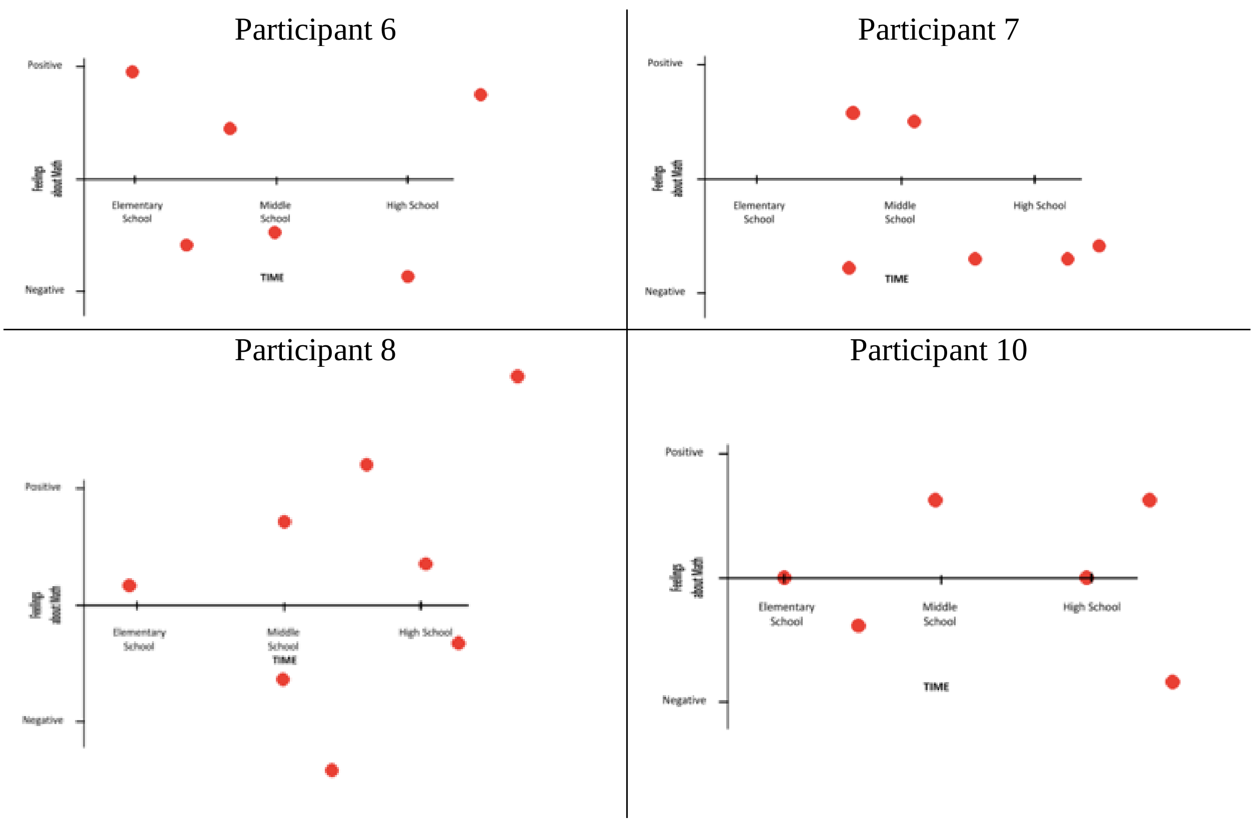
Participant 13 said her attitude "depends on what mathematics we're talking about." In her survey she said, "I like mathematics when it is hard but…I don't like mathematics when it is too easy. Therefore, I’m neutral when it comes to mathematics, I don’t hate it nor love it.” She clarified that she meant she likes the amount of work required to line up with how easy or challenging she finds the mathematics. She did not like when she had to show a lot of steps of work for a problem she can easily solve in her head. She preferred doing the mathematics her own way without jumping through the hoops of school mathematics to show the teacher her reasoning when the answer seemed obvious to her. Overall, her tone was neutral with three positive and three negative qualifiers about mathematics between her interview and autobiography. She focused more on the difficulty or ease of success in mathematics classes more than on liking or disliking various aspects of mathematics, though her attitude graph indicated that her feelings about mathematics correlated with her feelings about the genre of mathematics she was doing at each level. Like Participant 12, Participant 13 also terminated her graph with her experiences in high school. As it got more challenging in high school, she liked it more, whereas in late elementary and middle school, she tended to find the requirements of showing steps in middle school more tedious and annoying.

Like Participant 12, Participant 14 saw her neutral rating choice as an average of her experiences with mathematics. She wrote in her autobiography that after “a lifetime of going back and forth between liking and disliking [mathematics]” she feels “content” with it in her elementary content courses. She confirmed this idea in her interview, stating that a rating of 3 seemed like the best place “to kind of balance out the back and forth ideas that I had about mathematics throughout my childhood to now.” Her attitude graph, however, showed a steady decline in feelings about mathematics over time, but she said that her experiences in her elementary content courses (unrepresented in the graph) helped to keep her feeling neutral. In general, mathematics had never been a preferred school subject, and she saw herself more interested in reading, writing, and foreign language. Her overall tone about mathematics was relatively neutral, as between her autobiography and interview, she had eight positive qualifiers and nine negative qualifiers when discussing mathematics.

Dislike. All four participants who chose that they disliked mathematics on Q1 in the survey also expressed a strong, negative tone toward mathematics in their autobiographies and interviews. All four, however, indicated in their attitude graphs (see Figure 5.5) that they had positive feelings about mathematics at some point in their history. Participants 6 and 8 even indicated on their graphs a higher positive feeling about mathematics in their most recent experiences with it, despite choosing a 2 rating on the survey. All four participants' graphs and

Figure 5.5

Attitude graphs for participants indicating "disliking" mathematics (rating level 2).



stories indicated a roller-coaster relationship with mathematics, but ultimately the negative feelings outweighed the positive in their survey rating. Participants 7 and 10 were more likely affected by the timing of the survey, as they both were having poor college experiences with mathematics, including in their elementary mathematics content courses.

Participant 6 wrote of hating and despising mathematics by the end of her time in high school. She wrote that growing up, mathematics has given her anxiety since the third grade. Her overall tone was very negative, with seven negative qualifiers and only two positive qualifiers. One positive qualifier was her recalling liking mathematics before third grade and the other was in regard to her recent experiences in her elementary mathematics content course in college. She also indicated that she would have put a "strongly dislike" rating of 1 if it was not for the elementary mathematics content course she took the semester before the survey was taken.

Participant 7 expressed the most negative tone of all the dislikers. She used thirteen negative qualifiers and two positive when talking about mathematics. In her autobiography, she had nothing positive to say as she wrote about her dislike, which started in the fifth grade and continued through her first elementary mathematics content course in college. She wrote that her experiences have given her a "pessimistic attitude toward math" – namely, she does not expect a positive experience upon entering mathematics courses. She also mentioned in her interview that there were times where she did not hate the subject (e.g., in fifth grade when she had a tutor), and those experiences kept her from putting a 1 for her Q1 survey response. Most of her attitude toward mathematics seems to be joined with her struggles understanding the mathematics and her experiences with her teachers.

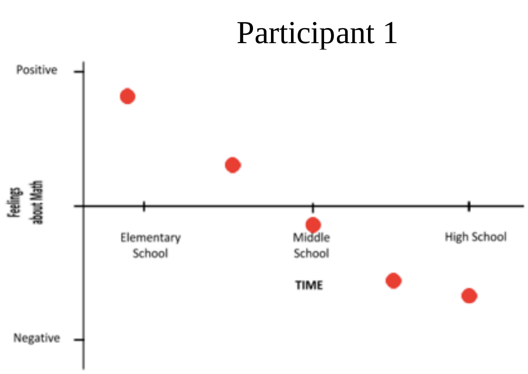
Participant 8 had perhaps the most interesting history of feelings toward mathematics, as seen in her graph depicting major extremes of negative and positive feelings toward mathematics. In fact, at the time of the survey, she was taking elementary mathematics content courses that she indicated had given her a very positive attitude toward mathematics. Yet, despite the fluctuation of her feelings about mathematics over time, she indicated that she still disliked it because of messages she received in middle school that as a girl, she was incapable of succeeding at mathematics like the boys could. She said she believed the message that she must not be “mathematics smart” and hence dreaded mathematics in high school. Thus, her feelings about mathematics were more driven by the messages she received from others than about the subject itself. Her tone was still negative when discussing mathematics itself, with five negative qualifiers and two positive. Also, her attitude rating selection was the opposite of those who chose based on recency as her attitude choice was the result of lingering feelings that began many years ago but remained despite individual positive or negative experiences.

Participant 10, like Participant 7, expressed more negative qualifiers (n=12) compared to positive (n=5) when writing about and discussing her rollercoaster relationship with mathematics. She said she did not want to choose a 3 rating because she saw that as neutral, and she “would prefer avoiding mathematics a little more” than considering herself neutral. Her tone verified that stance as she discussed the stress and anxiety mathematics caused her, how it made her feel defeated every day, and how she feared whatever mathematics class she had to take next. Her positive feelings about mathematics were tied to her feeling of understanding and her positive experiences with her teachers, and many of her negative feelings were tied to struggling in her mathematics classes. Again, her graph showed the variability of her attitude toward mathematics over time, but in her case, the negative feelings outweighed those that were positive despite mentioning some recent successes in her college elementary content courses.

Strongly Dislike. Participant 1 was the only participant in the entire whole group who indicated that she "strongly disliked" mathematics. Her tone was negative, with zero positive qualifiers when discussing mathematics and four negative. She wrote or spoke more about how she lacked the innate ability to do mathematics more than to explain her dislike for the subject. Even in Survey Question 2, her reason for dislike was simply "I have never been good at it." Her attitude graph (Figure 5.6) declined at a near constant rate over time, which she tied directly to her ever-increasing failure to succeed in her mathematics classes. These experiences culminated in her no longer caring about learning it in general at the end of high school. She gave no indication that her elementary content courses were improving her attitude toward mathematics, either. She seems to feel that some people get it and some people do not, and she falls into the latter category.

Figure 5.6

Attitude graph for participant indicating "strongly disliking" mathematics (rating level 1).



Summary. In summary, the interview participants' attitude graphs, as analyzed within each attitude rating category, revealed that participants made judgements about their attitudes and meanings of their rating choices differently from one another. Some participants chose an attitude rating based on the recency of their feelings toward mathematics, some chose based on an "average" of their positive and negative experiences, and others chose based on early feelings that were either reinforced or lingered over time. The graphing task was a beneficial activity in that it not only gave a visual of their judgements on which they based their attitudes, but it also depicted the variety of attitudes participants within each category carried toward mathematics over time.

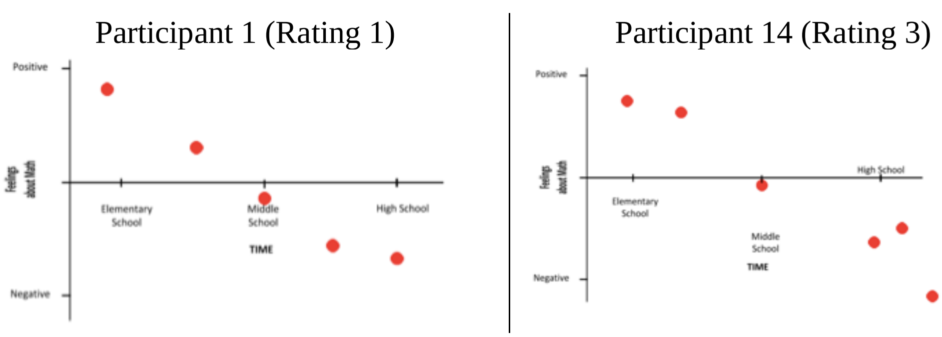
Attitudes in Similar Graphs

While above I give the results of analyzing the attitude graphs of participants within the various attitude ratings, here I present the results of analyzing graphs exhibiting similar patterns to see how participants located themselves differently on the attitude scale despite their similar graphs.

Linear Decline. Figure 5.7 shows the graphs of two participants who depicted their feelings about mathematics as declining in a linear fashion throughout their time in K-12 mathematics. Despite the similarity, Participant 1 rated herself as "strongly disliking"

Figure 5.7

Attitude graphs for participants with graphs declining in a linear fashion.

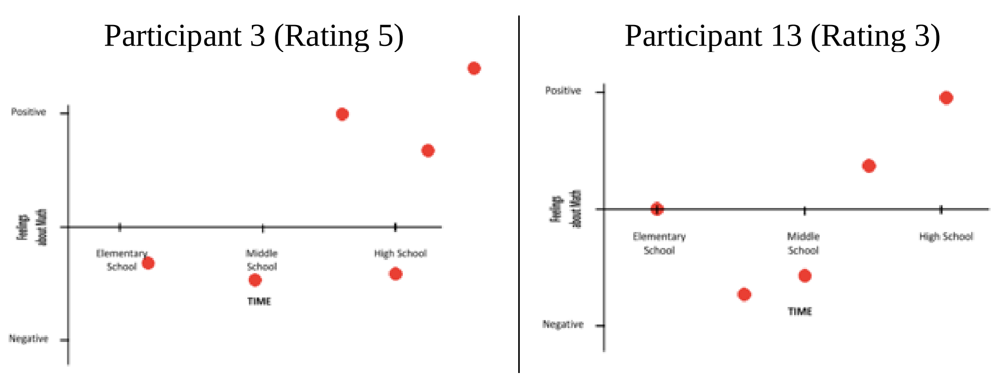


mathematics and Participant 14 rated herself as "neutral," despite the last point in her timeline being placed at the lowest part of the visible y-axis. This reveals a difference in how they interpreted their past experiences with mathematics in relationship to their answer to survey Q1. Participant 14 used a rating of 3 as an average of her experiences whereas Participant 1 displayed the recency effect of taking the survey near the lowest point of her feelings toward mathematics. This difference in rating may also be explained by Participant 14’s ability to look more broadly over her whole experience with mathematics and not be as affected by her recent negative experiences whereas Participant 1 holds more strongly to her recent experiences as they “supersede” her positive experiences in elementary school.

Upward Trend. Figure 5.8 shows the graphs of two participants whose attitudes toward mathematics trended upward as they approached the end of their K-12 experiences. Both seemed to experience a low point in late elementary or middle school before ending in the higher (positive) locations at the end of high school. Participant 3 rated herself as “strongly liking” mathematics, again suggesting a recency effect of taking the survey near her best experiences with mathematics, whereas Participant 13 rated herself as “neutral.” Like Participant 14 above, Participant 13 described her rating as an average of her experiences. Another explanation might be that Participant 3 has had an easier time moving on or forgetting the effects of her early experiences with mathematics on her attitude, whereas Participant 14 may still feel the effects of those experiences on her attitude.

Figure 5.8

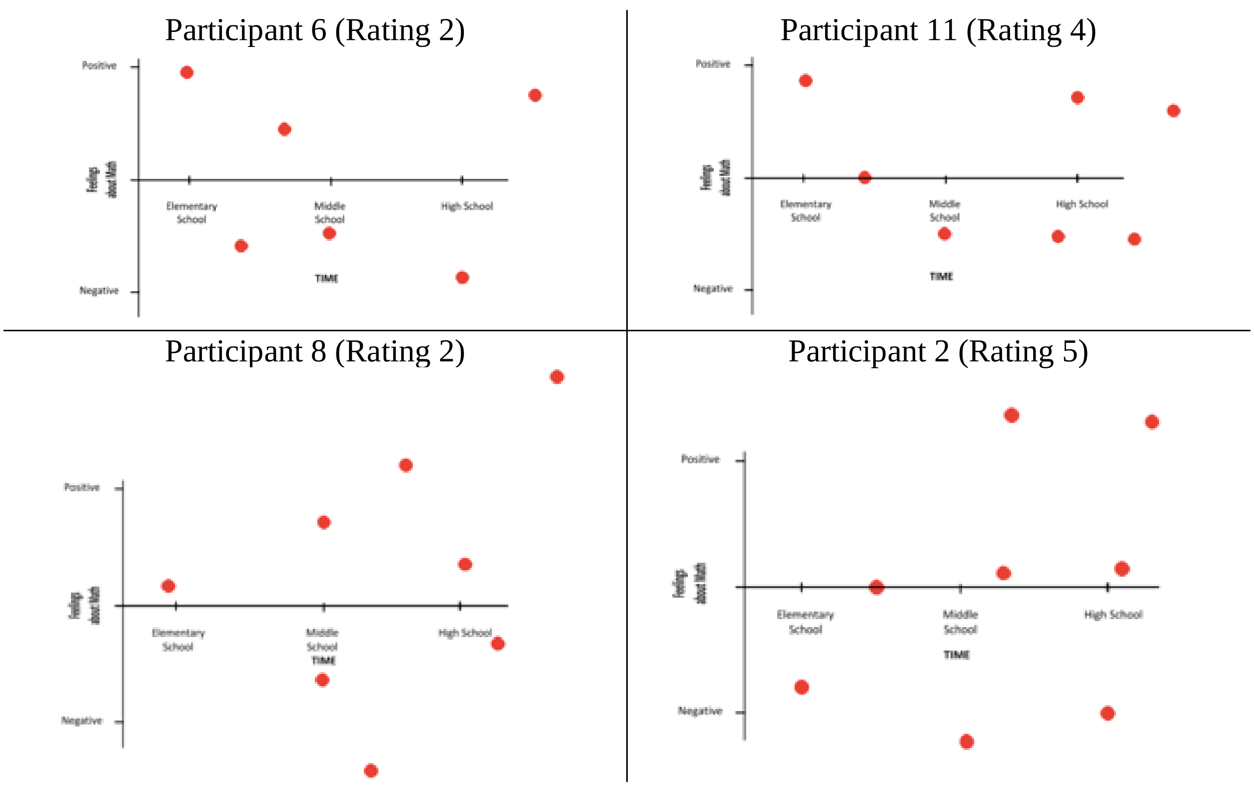
Attitude graphs that similarly show a late increase.



Rollercoaster. All four graphs in Figure 5.9 below include ups and downs in participants' feelings about mathematics over time, and all end in the positive realm. Participants 6 and 11 have similar starting and ending points, yet Participant 6 indicated disliking mathematics and Participant 11 indicated liking mathematics. Despite indicating a recent very positive feeling about mathematics as a result of her college experiences in her elementary mathematics content courses, Participant 6's high school experiences left a bad taste in her mouth that was not erased by recent positive events. Participant 11, however, found her experiences in college good enough to rate her attitude toward mathematics higher, again indicating the importance of the timing of the survey.

Figure 5.9

Attitude graphs that have a rollercoaster look, and end in the positive attitude realm.



Participants 8 (rating 2) and 2 (rating 5) also had rollercoaster experiences, with similarly very high ending points. The message Participant 8 received about girls not being capable in mathematics in elementary and middle school stuck with her throughout her experiences, even when she liked particular mathematics classes – including her college elementary mathematics content courses. Participant 2, however, indicated throughout her interview that her attitude changed with her experiences (she did not average her experiences), and her high numerical rating matches where she located her most recent positive experiences.

Summary. In summary, comparing similar graphs revealed how participants who recalled and depicted relatively similar feelings about mathematics over time judged their attitudes (via their rating choices) differently relative to those feelings. Yet again the graphing activity proved useful in justifying my argument that numerical ratings at the surface may not provide enough information about people's attitudes toward mathematics, as similar trends in attitudes over time resulted in numerous differences in attitude rating choices.

Chapter Summary

This chapter presented the results from my analysis to address the research question, *What is the overall landscape of attitudes toward mathematics amongst preservice elementary teachers?* Initial findings showed that this group of PSTs generally held non-negative attitudes toward mathematics. Out of the 112 total participants, 54 reported liking mathematics, 42 were neutral, and only sixteen reported disliking mathematics. I also found, however, that while most of the whole-group attitude ratings given in Survey Question 1 ("How I feel about mathematics is…") agreed with their responses to Survey Question 2 ("I feel that way because"), there were also an important number of disagreements between the two sets of responses. The most common rating level with disagreements was the "neutral" rating choice. Many participants emphasized negative aspects of mathematics or their experiences with mathematics, and none of the 42 neutral participants expressed only positive aspects.

Analyses of my interview participants' data revealed a more thorough picture of the complexity surrounding their self-assessed attitude rating level with respect to their attitude as it changed over time. Within each rating level (other than "strongly dislike" which had only one participant), interviewees' attitude graphs had different shapes and ended at different levels for participants within each group. Also, within each type of "graph shape," there were important differences in the ways the interview participants chose ratings levels for themselves. Some participants chose their attitudes based on the "recency effect" of their experiences relative to taking the survey, others chose a rating that represented an average of their experiences, and still others chose based on recalled experiences that were continually reinforced or left lingering feelings about mathematics on the whole that did not change regardless of positive or negative individual experiences with mathematics. Hence, the shape of their graph and last-depicted attitude level were not good predictors of which rating level they would choose for their attitude. These results exemplify the problem researchers encounter when asking participants to provide a numerical rating for their attitude toward mathematics, as their attitudes change and have a level of complexity that force-choice or Likert-scale surveys tend to ignore.

Chapter 6: Beliefs about Mathematics and its Relationship to Attitudes

In this chapter, I address my second research question, *What beliefs do preservice elementary teachers with positive and negative attitudes hold about the nature of mathematics?* Initially, I reviewed the survey results looking for any questions I had posed that seemed to produce responses related to beliefs. As a reminder, *beliefs about mathematics* includes any statements describing things people hold to be true about mathematics. I looked for both beliefs related to the nature of mathematics (e.g., Mathematics is a set of rules we need to memorize, mathematics is about solving equations) and beliefs grounded in participants' personal experiences but still expressing general truths about the subject (e.g., Mathematics is uninteresting, mathematics is fun). As such, beliefs differ from attitudes that focus on one's feelings (e.g., liking or disliking) in reaction to mathematics or to circumstances surrounding mathematics. For instance, the statement, "I think mathematics is rewarding because it builds upon itself and in its complexity over time," expresses both a positive attitude about mathematics (the speaker finds it rewarding) and a belief about mathematics (that it builds upon itself and becomes more complex over time).

Recall that my analysis of responses to Survey Question 2 identified many statements that, like the example above, cited beliefs about mathematics as a reason for the participant's attitude toward mathematics. Two other questions that included a promising number of beliefs statements were Survey Questions 6 ("What do you think mathematics is all about?") and 7 ("How do you see mathematics as different from other school subjects you like or dislike?"). Survey Question 6 (SQ6) was more designed to uncover beliefs about the nature of mathematics, while Survey Question 7 (SQ7) produced many beliefs statements that were comparative in nature: "I see mathematics as ______, while [other subjects] are more like ______."

Paralleling the previous chapter, I will first present the results of the whole-group analysis before those from the interviewee analysis. I will share the beliefs categories that resulted from the whole-group analysis, and how participants' beliefs foci changed when they shifted from thinking about mathematics is on its own versus in comparison to other subjects. I also share how both whole-group and interview participants with different attitudes toward mathematics expressed beliefs about mathematics similarly and, more often, differently.

Whole-Group Survey Results

I began this analysis by analyzing the responses to SQ6 that I intentionally designed to draw out participants' beliefs. First, I sorted my participants into groups based on their numerical ratings requested in Survey Question 1. There was only one response with rating 1 (Strongly Dislike), fifteen responses with rating 2 (Dislike), 42 responses with rating 3 (Neutral), 40 responses with rating 4 (Like), and fourteen responses with rating 5 (Strongly Like). I then looked for commonalities between responses to SQ6 within each rating level, and through an iterative process developed the eighteen categories of beliefs seen in Table 6.1.

Table 6.1

Belief categories developed from analysis of Survey Question 6 responses.

Belief Categories	**Examples from SQ6 Responses**
Mathematics is about problem solving.	"I think mathematics is all about problem solving."
Mathematics is unchanging and involves memorizing and applying rules, formulas, and equations.	"Once you learn one formula you will only use that formula or versions of that formula."
Mathematics involves relationships, connections, patterns, is like a puzzle, is changeable, and builds upon itself.	"I look at mathematics as kind of like a puzzle and you need to find all the pieces in order to complete it!"
Mathematics is applicable to how we think about and make sense of the real world, it is a useful daily tool.	"Mathematics is about making sense of the world around us."
Mathematics problems may have multiple answers or solutions and multiple ways of getting to the solution.	"I think mathematics is about…different ways to reach a solution."

Table 6.1 (cont'd)

Belief Categories	Examples from SQ6 Responses
Mathematics is about solving tasks to find an answer or solution.	"I think mathematics is all about finding the correct answer"
Mathematics involves logic, structure, is mechanical, and contains certain processes.	"Mathematics is about logic and carefulness."
Mathematics involves numbers, shapes, and quantifying things.	"I think mathematics is all about numbers"
Mathematics is a way for training our brain to think in certain ways (e.g., logically, enhance critical thinking and problem-solving skills) or to develop our character (e.g., dealing with struggle, working with others).	"I feel mathematics is a kind of way to improve a person's lots of abilities, like logical thinking ability (algebra, calculous), and spatial imagination (geometry)."
Mathematics is a universal language.	"I believe mathematics is a universal language."
Doing mathematics requires understanding.	"It's not memorization. It's not guessing. It's true understanding."
Mathematics is hard or does not make sense.	"it's a bunch of nonsense."
Mathematics is a gatekeeper or is important for future careers.	"For some people…the purpose of mathematics is to be successful in their careers"
Mathematics is a kind of ability; some have it, some don't.	"It is a kind of ability"
Mathematics involves working hard or trial and error.	"Mathematics is about trial and error."
Mathematics requires creative thinking.	"Thinking creatively and following an equation"
Mathematics requires its own way of thinking.	"It requires a certain kind of thinking."

Initially, I coded 180 statements from my 112 participants into the eighteen beliefs categories above. Some statements were divided and counted as multiple beliefs categories (e.g., "I think math is about problem solving…and math is all around us and many of us do not realize this" was split into two statements around the ellipsis), and some single statements fit into multiple categories (e.g., "Mathematics is about solving problems to find a solution" was coded as both *Mathematics is about problem solving* and *Mathematics is about solving tasks to find an answer or solution*). I followed this category development by identifying all responses to Survey Question 7 (SQ7) that expressed beliefs. I assigned the 93 SQ7 responses into the eighteen categories and developed new categories for beliefs that did not seem to fit the existing categories. This process resulted in the six additional beliefs categories seen in Table 6.2.

Table 6.2

Belief categories developed from analysis of Survey Question 6 responses.

Belief Categories	**Examples from SQ7 Responses**
Mathematics is black and white; it consists of problems with only one correct answer or solution and one way of getting there.	"Well most subjects are not black and white but I feel like mathematics is more black and white because there are right or wrong answers."
Mathematics brings stress, anxiety	"I see it as the most stressful and most anxiety filled topic for me."
There is no creativity in mathematics.	"Mathematics is different from language arts classes because it constricts your creativity"
Mathematics is easy.	"Mathematics is easy."
Mathematics is not/less applicable.	"I view mathematics as less enjoyable then other subjects such as science and social studies because it is less hands on and applicable to real life"
Mathematics is not engaging.	"mathematics…is also boring compared to other classes as formulas and equations are less exiting to look at then a lab or map, to me at least."

Once I completed the beliefs coding of all SQ6 and SQ7 responses, my mathematics education graduate assistant colleague once again reviewed my category assignments and made suggestions for any changes to the category descriptions themselves. Our consensus resulted in 192 total beliefs statements from SQ6 and 95 from SQ7. Tables 6.3 and 6.4 present the final agreed-upon results from this analysis. Results in the tables are grouped by attitude ranking level, including the total number of participants who responded to each survey question within each group. Categories used to code responses of one question, but not the other, are highlighted in yellow.

Table 6.3

Beliefs about mathematics expressed in responses to Survey Question 6.

Belief Category	1s N=1	2s N=14	3s N=42	4s N=40	5s N=14	Total N=111
Mathematics is about problem solving.	1	2	20	12	7	42
Mathematics is applicable to how we think about and make sense of the real world, it is a useful daily tool.	0	5	13	15	5	38
Mathematics involves numbers, shapes, and quantifying things.	1	4	11	10	2	28
Mathematics is about solving tasks to find an answer or solution.	0	5	4	6	3	18
Mathematics is a way for training our brain to think in certain ways (e.g., logically, enhance critical thinking and problem-solving skills) or to develop our character (e.g., dealing with struggle, working with others).	1	0	3	7	6	17
Mathematics problems may have multiple answers or solutions and multiple ways of getting to the solution.	0	2	2	6	0	10
Mathematics is unchanging and about memorizing and applying rules, formulas, and equations.	0	1	7	0	0	8
Mathematics involves logic, structure, is mechanical, and contains certain processes.	1	1	5	1	0	8
Mathematics involves relationships, connections, patterns, is like a puzzle, is changeable, and builds upon itself.	0	0	3	2	2	7
Mathematics involves working hard or trial and error.	0	0	1	1	2	4
Mathematics is a gatekeeper or is important for future careers.	0	0	2	2	0	4
Mathematics is a universal language.	0	1	0	0	1	2
Mathematics is hard or does not make sense.	0	1	1	0	0	2
Doing mathematics requires understanding.	0	1	0	0	0	1
Mathematics is a kind of ability; some have it, some don't.	0	0	0	1	0	1
Mathematics requires creative thinking	0	1	0	0	0	1
Mathematics Requires its own way of thinking	0	1	0	0	0	1
Total	4	25	72	63	28	192

Table 6.4

Beliefs about mathematics expressed by responses to Survey Question 7.

Belief Category	1s N=1	2s N=13	3s N=23	4s N=26	5s N=9	Total N=72
Mathematics is black and white; it consists of problems with only one correct answer or solution and one way of getting there.	1	12	8	12	6	39
Mathematics problems may have multiple answers or solutions and multiple ways of getting to the solution.	0	1	3	3	1	8
Mathematics involves logic, structure, is mechanical, and contains certain processes.	0	1	1	2	4	8
Mathematics is unchanging and about memorizing and applying rules, formulas, and equations.	0	0	4	2	0	6
Doing mathematics requires understanding.	0	0	4	2	0	6
Mathematics involves relationships, connections, patterns, is like a puzzle, is changeable, and builds upon itself.	0	0	0	3	1	4
Mathematics is about solving tasks to find an answer or solution.	0	0	2	1	1	4
Mathematics involves numbers, shapes, and quantifying things.	0	1	2	0	0	3
Mathematics is applicable to how we think about and make sense of the real world, it is a useful daily tool.	0	0	2	1	0	3
There is no creativity allowed in mathematics.	0	0	1	2	0	3
Mathematics is about problem solving.	0	0	0	0	2	2
Mathematics brings stress, anxiety	0	1	1	0	0	2
Mathematics is a kind of ability; some have it, some don't.	0	0	1	1	0	2
Mathematics is a universal language.	0	0	0	0	1	1
Mathematics involves working hard or trial and error.	0	0	0	1	0	1
Mathematics is easy.	0	0	0	1	0	1
Mathematics is not applicable.	0	0	1	0	0	1
Mathematics is not engaging.	0	0	1	0	0	1
Total	1	16	31	31	16	95

In response to SQ6, the most common belief participants expressed was that mathematics is about problem solving, but more frequently for most liking versus disliking mathematics. The second-most frequent belief expressed, and also the most evenly-distributed, was that mathematics helps us make sense of the world or is useful in our daily lives, such buying items in stores, calculating time and taxes, and cooking. Unlike the belief that mathematics is about problem solving, more of those who reported disliking mathematics shared the belief that mathematics is applicable to some aspect of the world or our daily lives with those who reported liking mathematics.

In response to SQ7, many participants (*n*=39) expressed the belief, *Mathematics is black and white; it consists of problems with only one correct answer or solution and one way of getting there.* In their SQ6 responses, no one wrote about mathematics as being about finding ONE solution or doing THE right method for finding a solution, yet it was by far the most frequent belief expressed in response to SQ7 and was expressed by participants in all five rating groups. Many wrote about mathematics as concerning finding solutions or answers, but in response to SQ7 more focused on there was only one answer or a particular solution method to find each answer. I also found that the responses describing mathematics as a way of training our brains to think in certain ways disappeared when participants were asked to compare mathematics to other school subjects. This was surprising since it was so frequently mentioned in SQ6 responses, especially among those with positive attitudes toward mathematics. One reason for these differences between responses to SQ6 and SQ7 may lie in that SQ6 asked participants to focus on aspects of *doing* mathematics where SQ7 asked about differences that they liked or disliked about the subject. For the latter, they tended to focus on mathematics' lack of subjectivity in relation to other subjects. Some liked this perceived aspect of mathematics while others disliked it.

Whole-group Beliefs as Related to Attitudes

Survey Questions 6 and 7. Since Research Question 2 focused specifically on analyzing the beliefs of those who like or dislike mathematics, I combined the results from SQ6 and SQ7 in order to look for themes within and between those who expressed liking mathematics (ratings 4 and 5), those who expressed disliking mathematics (ratings 1 and 2), and those who were neutral (rating 3). Table 6.5 shows the total combined responses from SQ6 and SQ7 for each belief category across these three attitude categories (dislike, neutral, like).

Table 6.5

Beliefs expressed in responses to SQ6 and SQ7, assigned to Dislike, Neutral, and Like.

Belief Category	Dislike N=16	Neutral N=42	Like N=54	Total N=112
Mathematics is about problem solving.	3	20	21	44
Mathematics is applicable to how we think about and make sense of the real world, it is a useful daily tool.	5	15	21	41
Mathematics is black and white; it consists of problems with only one correct answer or solution and one way of getting there.	13	8	18	39
Mathematics involves numbers, shapes, and quantifying things.	6	13	12	31
Mathematics is about solving tasks to find an answer or solution.	5	6	11	22
Mathematics problems may have multiple answers or solutions and multiple ways of getting to the solution.	3	5	10	18
Mathematics is a way for training our brain to think in certain ways (e.g., logically, enhance critical thinking and problem-solving skills) or to develop our character (e.g., dealing with struggle, working with others).	1	3	13	17
Mathematics involves logic, structure, is mechanical, and contains certain processes.	3	6	7	16

Table 6.5 (cont'd)

Belief Category	Dislike N=16	Neutral N=42	Like N=54	Total N=112
Mathematics is unchanging and about memorizing and applying rules, formulas, and equations.	1	11	2	14
Mathematics involves relationships, connections, patterns, is like a puzzle, is changeable, and builds upon itself.	0	3	8	11
Doing mathematics requires understanding.	1	4	2	7
Mathematics involves working hard or trial and error.	0	1	4	5
Mathematics is a gatekeeper or is important for future careers.	0	2	2	4
There is no creativity allowed in mathematics.	0	1	2	3
Mathematics is a kind of ability; some have it, some don't.	0	1	2	3
Mathematics is a universal language.	1	0	2	3
Mathematics brings stress, anxiety	1	1	0	2
Mathematics is hard or does not make sense.	1	1	0	2
Mathematics is easy.	0	0	1	1
Mathematics is not applicable.	0	1	0	1
Mathematics is not engaging.	0	1	0	1
Mathematics requires creative thinking	1	0	0	1
Mathematics Requires its own way of thinking	1	0	0	1
Total	46	103	138	287

Mathematics is about problem solving was the most frequently expressed, followed by *Mathematics is applicable to how we think about and make sense of the real world, it is a useful daily tool*, and *Mathematics is black and white; it consists of problems with only one correct answer or solution and one way of getting there*. The first two were heavily influenced by the SQ6 results, and the last one came entirely from responses to SQ7. I first discuss the similarities across the three groups of participants before turning to differences.

Participants' comments about mathematics being about problems solving were all very similar, with nearly all writing something like "math is about problem solving" or "math is about solving problems." All three attitude groups tended to view mathematics as being applicable to how we make sense of the world and as useful in our daily lives. Participants across all attitude levels were about evenly divided between describing mathematics as a way to make sense of the world or universe and as being a useful tool in our daily activities, with many of them writing about both things. I could not discern differences in how participants frequently in the three attitude levels thought about *Mathematics involves numbers, shapes, and quantifying things; Mathematics involves logic, structure, is mechanical, and contains certain processes;* and *Mathematics is about solving tasks to find an answer or solution*. Only one participant's contribution to *Mathematics problems may have multiple answers or solutions and multiple ways of getting to the solution, and it allows you to think creatively* focused on mathematics problems having multiple answers, writing "there are many answers," though she did not clarify that statement. The rest of the responses in the category focused on mathematics having multiple ways or methods of finding solutions.

All three attitude groups also produced statements coded in the category *Mathematics is black and white; it consists of problems with only one correct answer or solution and one way of getting there,* but did so differently. Those who gave "dislike" or "neutral" numerical ratings of 1, 2, or 3 described mathematics as leaving little room for "outside the box" thinking and requiring certain steps to reach the one right answer. Nearly all of them added that they did not like that aspect of mathematics. Those who gave "like" ratings of 4 or 5, however, wrote that mathematics was "black and white," "straightforward," has "no gray area," and "always has an answer" and liked these aspects. Contrary to their disliking and neutral counterparts, however, likers tended to see mathematics as also allowing for more than one way to solve tasks or problems despite generally agreeing upon there being one answer to work toward. Hence, the responses of likers were coded into two categories. For example, "only one answer to work toward" part was coded as *Mathematics is black and white; it consists of problems with* ***only one***

correct answer or solution *and one way of getting there* category and the “more than one way to solve tasks or problems” part into the *Mathematics problems may have multiple answers or solutions and* ***multiple ways of getting to the solution****, and it allows you to think creatively* category.

With respect to differences, very few participants who indicated disliking mathematics reported viewing mathematics as being about problem solving. Similarly, only one negative-attitude participant indicated seeing mathematics as a means for improving one’s problem-solving, logical thinking, or critical thinking skills or as a means for developing one’s character, whereas a number of participants with positive attitudes saw it as such. Most striking, however, was that no disliking participants saw mathematics as being about relationships, connections, or patterns or as being changeable or building upon itself. While three neutral participants did, two of the three focused on the patterns aspect, with the other expressing the belief that mathematics is about understanding “how problems work together.” Beliefs that mathematics is about relationships, connections, is expanding and changeable, and that it involves problem solving are generally healthy beliefs about the nature of mathematics, and hence, it is notable that so few on the lower end of the attitude spectrum saw mathematics in that way. Instead, while they did focus some on its applicability to life (a good thing), they also tended to focus their responses on the aspects of mathematics they encountered in their school mathematics experiences (e.g., equations, numbers, finding an answer) and on its limiting factors (e.g., but one way of finding an answer).

Survey Question 2 and Autobiographies. After developing the beliefs categories and analyzing the results from Survey Questions 6 and 7, I reviewed responses to Survey Question 2 (SQ2), which asked participants to give a reason for their Survey Question 1 attitude rating.

Many participants expressed that various beliefs about mathematics impacted their attitudes in their responses. I took the beliefs statements from my previous analysis of the SQ2 responses and assigned them to the belief categories developed in the SQ6 and SQ7 analysis. From that process, with two new categories emerged – *Mathematics has too much homework* and *Mathematics is engaging or fun*. Table 6.6 below shows the most common beliefs categories in which their responses fell, again distinguished by numerical attitude rating. Table 6.6 omits categories with two or fewer total responses (which included the new category about homework) due to their low frequency.

Table 6.6

Beliefs expressed in responses to SQ2, assigned to Dislike, Neutral, and Like.

Belief Category	**Dislike N=7**	**Neutral N=15**	**Like N=30**	**Total N=52**
Mathematics is engaging or fun.	0	1	17	18
Mathematics is hard or does not make sense.	6	8	1	15
Mathematics consists of problems with only one correct answer or solution and one way of getting there. It is black and white, you are either right or wrong.	0	1	7	8
Mathematics involves relationships, connections, patterns, is like a puzzle, is changeable, and builds upon itself.	0	0	3	3

Perhaps because SQ2 asked specifically for participants to explain why they chose their attitude level, their most commonly reported belief responses are strikingly different between attitude groups. The top two categories are not surprising; it makes sense that those who like mathematics would find it rewarding, interesting, or fun while those who dislike mathematics would not. It also makes sense that those in the dislike or neutral category would be more likely to view mathematics as difficult or confusing than those who like it. The bottom two categories present more interesting information. Those who liked mathematics wrote about liking that mathematics has one correct solution, is black and white, is about relationships, or is like a puzzle, while no one in the dislike category expressed such beliefs as a reason for disliking mathematics. In fact, all of the beliefs statements expressed by those in the dislike category in response to SQ2 related to their experiences with mathematics – namely, they wrote about it being difficult, boring, or confusing. On the other hand, nearly half of responses that fell into the like category (17 of 36 total) pointed to beliefs about the nature of mathematics – as opposed to beliefs connected to experiences – as reasons for liking it (e.g., "I like there is always a right or wrong answer, "Each problem has one answer that can be proven").

In analyzing the same autobiographies I had selected randomly for analysis in Chapter 7 (recall from methods, that I did the analysis for my later research questions before returning to research question 2), I found only 26 total beliefs statements written by nineteen of the 57 whole-group participants in my sample. The results of my analysis of beliefs written in the autobiographies can be seen in Table 6.7 below.

Table 6.7

Beliefs expressed in Mathematics Autobiographies, assigned to Dislike, Neutral, and Like

Beliefs Category	Dislike N=5	Neutral N=5	Like N=9	Total N=19
Mathematics is black and white; it consists of problems with only one correct answer or solution and one way of getting there.	0	1	4	5
Mathematics problems may have multiple answers or solutions and multiple ways of getting to the solution.	0	1	2	3
Mathematics is not applicable.	2	1	0	3
Mathematics involves relationships, connections, patterns, is like a puzzle, is changeable, and builds upon itself.	0	0	2	2
Mathematics is applicable to how we think about and make sense of the real world, it is a useful daily tool.	1	1	0	2

Table 6.7 (cont'd)

Beliefs Category	Dislike N=5	Neutral N=5	Like N=9	Total N=19
Mathematics is unchanging and about memorizing and applying rules, formulas, and equations.	0	0	2	2
Mathematics is not engaging.	1	1	0	2
Mathematics is a gatekeeper or is important for future careers.	0	1	0	1
Mathematics is easy.	1	0	0	1
Mathematics is hard or does not make sense.	0	0	1	1
Mathematics is engaging or fun.	0	0	1	1
Mathematics is essential and should be learned.	1	0	0	1
Everyone can do mathematics.	1	0	0	1
Doing mathematics well means doing it fast.	0	0	1	1
Total	7	6	13	26

No participants in the sample expressed more than two beliefs, and only three beliefs categories registered more than two responses – *Mathematics is black and white; it consists of problems with only one correct answer or solution and one way of getting there; Mathematics problems may have multiple answers or solutions and multiple ways of getting to the solution*, and *Mathematics is not applicable*. Like the responses to SQ1, the majority of participants for the first two categories came from those in the "Like" group (there were none from the dislike group), while two dislike participants and one neutral participant found mathematics to be inapplicable to their lives. The three new beliefs categories that emerged after reading the sample of autobiographies were *Mathematics is essential and should be learned*; *Everyone can do mathematics* (interestingly both written by dislikers), and *Doing mathematics well means doing it fast* (written by a liker).

Cumulative Whole-Group Results. Table 6.8 gives the cumulative side-by-side view of all of the beliefs statements made in Survey Questions 2, 6, and 7 and the Mathematics Autobiographies.

Table 6.8

Whole-group combined beliefs results from SQ2, SQ6, SQ7, and Mathematics Autobiographies.

Beliefs Category	Dislike N=16	Neutral N=42	Like N=54	Total N=112
Mathematics is black and white; it consists of problems with only one correct answer or solution and one way of getting there.	13	10	29	52
Mathematics is about problem solving.	3	20	22	45
Mathematics is applicable to how we think about and make sense of the real world, it is a useful daily tool.	6	17	21	44
Mathematics involves numbers, shapes, and quantifying things.	6	13	12	31
Mathematics problems may have multiple answers or solutions and multiple ways of getting to the solution.	3	6	14	23
Mathematics is about solving tasks to find an answer or solution.	5	6	11	22
Mathematics is a way for training our brain to think in certain ways (e.g., logically, enhance critical thinking and problem-solving skills) or to develop our character (e.g., dealing with struggle, working with others).	1	3	15	19
Mathematics is engaging or fun.	0	1	18	19
Mathematics is unchanging and about memorizing and applying rules, formulas, and equations.	1	12	5	18
Mathematics is hard or does not make sense.	7	9	2	18
Mathematics involves logic, structure, is mechanical, and contains certain processes.	3	7	7	17
Mathematics involves relationships, connections, patterns, is like a puzzle, is changeable, and builds upon itself.	0	3	13	16
Doing mathematics requires understanding.	1	4	2	7
Mathematics is a gatekeeper or is important for future careers.	0	3	2	5
Mathematics involves working hard or trial and error.	0	1	4	5
Mathematics is not engaging.	2	3	0	5
Mathematics is not applicable.	2	3	0	5
Mathematics is a universal language.	1	0	3	4
There is no creativity allowed in mathematics.	0	1	2	3

Table 6.8 (cont'd)

Beliefs Category	Dislike N=16	Neutral N=42	Like N=54	Total N=112
Mathematics is a kind of ability; some have it, some don't.	0	1	2	3
Mathematics brings stress, anxiety	1	1	0	2
Mathematics has too much homework	0	1	1	2
Mathematics is easy.	1	0	1	2
Mathematics Requires its own way of thinking	1	0	0	1
Mathematics is essential and should be learned.	1	0	0	1
Everyone can do mathematics.	1	0	0	1
Mathematics involves speed, doing it well means doing it fast.	0	0	1	1
Mathematics requires creative thinking	1	0	0	1
Total	60	125	187	372

Once the results were combined, the most commonly expressed belief in the whole group was *Mathematics is black and white; it consists of problems with only one correct answer or solution and one way of getting there.* It was also the only category that seemed to have noticeable change appear when the groups were combined. From the initial time this code showed up in the SQ7 analysis results in Table 6.4, the biggest change was for the "like" group that gained eleven more statements. The majority of the 29 statements from the likers focused on there being one answer to find, whereas the majority of the thirteen statements from the dislikers focused on only one way to do mathematics.

Not much changed for other top categories in this combined view from the tables above in which they first appeared. For instance, *Mathematics is about problem solving* barely changed from its Survey Question 6 analysis origination (Table 6.3), gaining only three more Likers across the other areas of analysis. The next top category, *Mathematics is applicable to how we think about and make sense of the real world, it is a useful daily tool,* gained six participants through analyses after SQ6, but relative to the total (N=44) that is not a major change. Other top categories, such as *Mathematics involves numbers, shapes, and quantifying things*; *Mathematics* *is about solving tasks to find an answer or solution*; and *Mathematics is a way for training our brain…* all remained top categories with little change in their totals after the initial SQ6 analysis.

The category that seemed to change the most in this combined view was *Mathematics problems may have multiple answers or solutions and multiple ways of getting to the solution*. Each level of analysis (SQ6, SQ7, SQ2, and Autobiographies) produced a decent number of statements that were coded into this beliefs category, but combined it registered as one of the top categories overall. Also interesting was that likers, dislikers, and neutrals for the most part agreed that there is only one answer or method (as shown in the top belief category), whereas the majority of statements about there being multiple solution paths (as seen in the multiple answers or solution paths category) came far more often from the likers than neutrals or dislikers.

Interview Participants' Beliefs

I analyzed the interview participants' interview transcripts for statements that expressed their beliefs about mathematics. I included unsolicited statements of belief as I had done in the autobiographies previously. I also included responses to my interview questions that indicated a belief. For example, I asked a participant "Do you think there are mathematics people and non-mathematics people?" to which she responded, "Yes, for sure." I saw her agreement as expressing a belief that mathematics is a kind of ability that some have, and some do not.

Table 6.9 summarizes these belief statements. Recall that the interviews were tailored to each participant's survey responses and hence, so participants did not all have an equal opportunity to expand upon the beliefs they may have expressed in SQ6 and SQ7. For one reason, when survey statements were quite clearly written, I did not follow up in the interview.

Table 6.9

Beliefs Expressed in Interviews by Interview Participants

Beliefs Category	**1s**	**2s**	**3s**	**4s**	**5s**	**Total**
Mathematics problems may have multiple answers or solutions and multiple ways of getting to the solution.	1	3	2	2	3	11
Mathematics is black and white; it consists of problems with only one correct answer or solution and one way of getting there.	3	2	0	1	3	9
Mathematics is applicable to how we think about and make sense of the real world, it is a useful daily tool.	1	3	1	1	3	9
Mathematics is a kind of ability; some have it, some don't.	1	5	0	0	0	6
Everyone can do mathematics.	0	0	0	2	1	3
Mathematics is a way for training our brain to think in certain ways (e.g., logically, enhance critical thinking and problem-solving skills) or to develop our character (e.g., dealing with struggle, working with others).	0	1	0	2	0	3
Mathematics requires creative thinking.	1	0	0	0	1	2
Mathematics is about solving tasks to find an answer or solution.	0	1	0	1	0	2
Mathematics involves numbers, shapes, and quantifying things.	0	1	0	0	0	1
Mathematics is a gatekeeper or is important for future careers.	0	0	0	1	0	1
Mathematics involves relationships, connections, patterns, is like a puzzle, is changeable, and builds upon itself.	0	0	0	1	0	1
Mathematics is not applicable.	0	1	0	0	0	1
Mathematics is about problem solving.	0	0	1	0	0	1
Total	7	17	4	11	11	50

The first three categories of beliefs in Table 6.9 were most-commonly expressed, and fairly consistently across attitude groups. One reason for the consistency in the top two categories is because when a participant would express a belief about mathematics that there was one right answer or one right way of getting the answer (the second category of the table), I would press them to discuss it more. That discussion often resulted in their acknowledgement that their belief had changed recently to there being more than one way to solve mathematics problems (the top category). For instance, Participant 1 (a "strong disliker") stated that in her K-12 school experience, there was "the formula you have to use and that's how you're going to get your final answer. And if you don't do that, you're not going to get the answer...you're not going to get the points for it." I asked her if she believes there is one answer and one method that the instructor wants, and she replied that she does believe that. However, she stated further, "nowadays the professors I've had have shown multiple ways of getting problems done and different formulas or different routes you can take to get the answer," acknowledging that her belief had changed due to this experience in her college mathematics courses. Participants 2 and 5 (strong likers), and 9 (liker) also acknowledged holding beliefs before college that there was one answer and one way of getting there, but now believed there are multiple paths to a right answer.

The third belief listed in the table, *Mathematics is applicable to how we think about and make sense of the real world, it is a useful daily tool,* was a common response because I asked all participants how they see mathematics in relationship to the world. Its frequency (n=9) is less than the total number of interviewees (n=14), first because Participants 6 (disliker) and 14 (neutral) said "I don't know" to both the question and my attempts to clarify it. Secondly, Participant 7 (disliker) and Participants 4 and 11 (likers) responded saying mathematics was created as a way to help our brains to think logically and teach us certain problem-solving skills. Note that saying mathematics is a way to teach our brains problem-solving skills was coded as distinct (and hence, not double coded) from mathematics being *about* problem solving. Participant 12 (neutral) responded by saying that all mathematics is "just all about solving the problem," and hence had her response placed in the *Mathematics is about problem solving* category.

The most interesting belief that arose from the interviews was *Mathematics is a kind of ability; some have it, some don't* because of the polarity of the responses between likers and dislikers. All five participants in the “dislike” and “strongly dislike” categories said in some way that there are mathematics people and non-mathematics people, that some people have their brain wired toward mathematics or not, or in Participant 8’s case, at least during her time in K-12, that if you were a girl, you could not be good at mathematics. Participant 10 (disliker) did acknowledge some doubt about her agreement with the statement that there were mathematics and non-mathematics people when she added that she believes all people *can* learn it. She clarified that some people seem to have a special gift for it, and she was not one of those people. No one at a neutral attitude level or above expressed statements of this nature. Participants 4 and 11 (likers) and Participant 5 (strong liker) all said explicitly – when asked– that they do not believe mathematics is a kind of ability or that there are mathematics and non-mathematics people (hence these statements were coded in the *Everyone can do mathematics* category).

A second result from my interview analysis was the continued (from the whole-group analysis) expression of different belief statements that were oppositional in nature. The top two beliefs in Table 6.9 are one such set. Participants discussed either that mathematics allows for multiple paths to a solution, or that there is only one solution path, or in some cases, both (signifying a change in their beliefs over time or because of a certain experience). Participants more frequently focused in the singularity/multiplicity of answer than thinking of mathematics as allowing multiple solution possibilities, so that second part of the opposition was less visible in the data. A second set of oppositional beliefs were *Everyone can do mathematics* and *Mathematics is a kind of ability; some have it, some don’t*. This pair tended to align with oppositional attitudes as well – likers tended to believe the former whereas dislikers tended to believe the latter.

The Role of Others on Beliefs

One general theme that emerged from the interview analysis concerned the roles that others play in shaping beliefs, and unfortunately, most of it was relayed negatively. The most frequently identified "others" were teachers. Of my dislikers, Participants 1, 6, 7, and 8 all mentioned that their K-12 experiences involved teachers who required that they carry out mathematical work in particular and apparently arbitrary ways: To write their mathematical answers in a certain format, solve problems a certain way, show certain work to get full credit, or use certain formulas at particular time. While Participants 1, 7, and 8 mentioned their beliefs had changed in a positive way due to experiences with professors at the college level who encouraged multiple approaches to problem solving, Participants 6 did not indicate that her beliefs on the matter had changed. "Neutral" Participants 13 and 14 described experiences similar to those Participants 1, 7, and 8 has indicated; their K-12 teachers influenced their beliefs that they had to write answers or solve problems a certain way before their experiences in college (particularly in elementary mathematics content courses) changed those beliefs in a positive way.

Participant 8 relayed a tragic story about the role of her teachers, counselor, and community had played in shaping her childhood belief that mathematics is for boys, not girls. Despite succeeding (i.e., receiving high grades) at every level in mathematics, Participant 8 said the message she received was, "Girls aren't good at mathematics. You're a girl. You shouldn't be good at mathematics. You don't have to be good at mathematics." This belief was reinforced when, despite her success and top-two placement in her mathematics class in middle school, she was not moved to high-school algebra with the similarly-achieving boys and was forced instead to repeat pre-algebra. She said it also did not help that her father, who was "way better at mathematics" than her mom, said the belief that girls should not be good at mathematics was "kind of this societal thing that's just been repeated over and over and over around me."

Among Likers, Participant 9 expressed that some of her teachers had marked her incorrect even if her solution to a mathematics problem was correct, but presented in an unfamiliar manner or used an approach not taught by that teacher. She said that if she was not understanding the teacher, "I would go and investigate, I guess you'd say, like different ways to do it," and she would get frustrated when teachers told her she was wrong. Some teachers said explicitly that they were going to mark her wrong because she did not solve the problem using their method. Participant 2 said she felt, at least until she reached calculus, that "it was pushed on us that there was one way to do mathematics and one way to get an answer." She said calculus was the time she finally realized that people can take many approaches to solving mathematics problems and still arrive at the same solution.

In contrast to other interview participants, Participant 4 wrote in her autobiography and discussed in detail in her interview that her peers influenced her beliefs about mathematics in middle school. She stated that hearing so many friends discussing how awful and hard mathematics was in middle school led her to believe what she repeatedly called "the [negative] stigma" that society holds about mathematics. This belief changed not only when she experienced success in the subject and found enjoyment helping others, but also because she had a positive influence at home in her brothers, one of whom especially enjoyed mathematics. She also said her calculus professor in college helped her come to believe there were multiple ways to solve problems, though she had not previously expressed believing there was only one way to solve them.

Other Observations about Beliefs

Unstable Aspect of Beliefs. As shown above in numerous examples, participants' interviews highlighted that beliefs can change and sometimes change quickly. In the above paragraphs, I highlighted how Participants 1, 2, 4, 7, 8, 13, 14 all experienced some substantial change in their beliefs. Many involved shifting from beliefs that there was one way to solve mathematics problems to beliefs that there could be multiple ways to solve them. Participant 7 also expressed finding mathematics to be a boring subject in middle school, and not seeing any purpose to it. She indicated that she now saw it as "something created in schools to help with teamwork, problem-solving skills, just develop those skills in the brain that are needed for whatever profession," but did not mention the reasons for this shift. Participant 4 mentioned the "stigma," but due to her home influences, her achievement, and her enjoyment helping others with mathematics, she was able to move past it.

Attitudes Influenced by Beliefs. As was true for the sample as a whole, some interview participants expressed that their attitudes were shaped by their beliefs in some way, currently or in the past. In fact, eight of the thirteen beliefs statements from Table 6.9 were linked overtly to attitudes, while others could probably be assumed based on the context. For example, Participant 8 said that her dislike of mathematics was heavily influenced by the societal message she received that, as a female, she does not belong in mathematics. Participant 4 mentioned that she found mathematics so "satisfying" when she solves problems because "mathematics is one of the more involved subjects to where you have to use so many different topics or sections." She went on to indicate the satisfaction of getting answers out of all that complexity, "I don't know if I've gotten that feeling out of any other subject." Participants 5 (a liker) and 8 (a disliker) both said they did like that there was generally one right answer or solution in mathematics.

Chapter Summary

In this chapter, I presented the results addressing my second research question, *What beliefs do preservice elementary teachers with positive and negative attitudes hold about the nature of mathematics?* I developed beliefs categories based on the responses participants gave to questions about what they thought mathematics was all about and how it compared to other subjects. When asked what mathematics is all about, participants' responses focused mostly on what it means to them to *do* mathematics, most commonly providing statements falling in the categories *Mathematics is about problem solving*; *Mathematics is applicable to how we think about and make sense of the real world, it is a useful daily tool;* and *Mathematics involves numbers, shapes, and quantifying things.* Responses in these categories not explicitly connected to statements of attitude; no one wrote statements like "I like/dislike that mathematics is about problem solving" or "I like/dislike that mathematics is about quantifying things." Though responses to Survey Question 6 generally included fewer statements of feeling, dislikers tended to see mathematics less as about problem solving than likers and more about finding answers or solutions than likers. Both groups saw mathematics as generally similarly as useful in their daily lives or for making sense of the world and as involving numbers, shapes, and as useful in assigning quantities to things.

When asked how it compares to other subjects, participants most often expressed beliefs about mathematics' lack of subjectivity as compared to other subjects, with answers most commonly falling in the category *Mathematics is black and white; it consists of problems with only one correct answer or solution and one way of getting there.* Participants who disliked mathematics tended to see the lack of subjectivity as restrictive, whereas likers tended to be positive about the right or wrong, black and white nature of mathematics. No one mentioned this aspect of mathematics when asked what mathematics was all about. Apparently, they saw it as an aspect setting mathematics apart from other areas of study, but not necessarily as THE defining characteristics of mathematics. Analyses of Survey Question 2 (that asked for their reasons for their attitudes) and the autobiographies further solidified that likers tended to like this black-and-white aspect of mathematics more-so than dislikers.

Interviews with participants provided further evidence that some students enter their teacher preparation programs carrying beliefs about mathematics that are oppositional to those of their peers. A number of whole-group participants expressed beliefs that there is little flexibility in solving mathematics problems whereas others expressed room for creativity and multiple solution pathways, and this was true for interview participants as well. Interview dislikers tended to see mathematics as a kind of ability that some have and others do not. In fact, all five dislikers stated or agreed with the idea that there are mathematics people and non-mathematics people. No neutral participants made statements about it, but three of the six likers stated explicitly that they believed this belief not to be true, hence expressing the oppositional belief that everyone can do mathematics.

The interviews also provided evidence unseen in the whole-group analysis that beliefs can change in a relatively short amount of time, even when the belief had been reinforced for most or all of participants' K-12 experiences. Eight interviewees said that at one time or another they held, and had reinforced by teachers, the belief that there was one way to solve mathematics problems (generally, the teacher's way). Five of the eight also acknowledged that their belief had changed due to their experiences in high school or college, when teachers or instructors expressed the belief that there are always multiple ways to solve problems and encouraged them to explore their own ways of doing so. Also unseen in the whole-group results was the influence others, especially teachers, had on participants' beliefs about mathematics and how often these were negative.

Each layer of beliefs analysis – from the survey questions to the autobiographies and interview transcripts – expanded the list of expressed beliefs. As evidenced in the progression of tables in this chapter, the diversity of beliefs increased as I moved from analyzing one question or activity to the next, while the most common beliefs expressed by participants in the early survey questions analyses remained relatively constant from the early analyses to the end. The three most common beliefs expressed in the whole group data – that mathematics is about solving problems, that mathematics solutions have only one solution or only one way of finding the solution, and that mathematics is about making sense of the world or that it is useful in day-to-day functioning – continued to surface in every other level of analysis even as the list of beliefs expressed continued to expand.

Also important to acknowledge is that the different ways I asked questions influenced the beliefs that emerged. The highlighted beliefs categories in Tables 6.3 and 6.4 accentuate this fact. SQ6, which asked what mathematics is all about, and SQ7, which asked participants how they see mathematics as different from other school subjects, produced beliefs that were unique to each question. While there were a number of beliefs categories that remained consistent and expressed similarly in each round of analysis, some very commonly expressed beliefs would not have arisen without asking multiple questions aimed at uncovering participants' beliefs or by having them write about their reasons for their attitudes and about their relationships with mathematics over time. Hence, their interactions with their memories about their feelings about mathematics also produced beliefs that would not have otherwise been expressed.

Chapter 7: Relevant Mathematical Experiences in the Formation of Attitudes

In this chapter, I extend the focus begun in Chapter 5 on my participants' attitudes toward mathematics by presenting the results pertaining to the experiences and turning points they reported as relevant in the formation of their attitudes. The chapter first attends to my third research question, *What experiences do preservice elementary teachers attribute to having shaped their attitudes and beliefs about mathematics?* Though I am focusing this chapter on the formation of attitudes from experience, I also found, as reported in the last chapter, many instances where they attributed their feelings about mathematics to certain beliefs (e.g., "I like mathematics because in mathematics there is a right and wrong answer…mathematics for the most part is black and white"), which I described in Chapter 6 and will return to in this one. As a reminder, I considered statements related to their feelings about mathematics (e.g., like, dislike, love, hate) as indicating attitudes and statements describing what they hold to be true about mathematics – whether in relationship to their experiences or generally (e.g., mathematics is fun, mathematics is about problem solving) as beliefs.

In presenting my results, I again begin with my whole-group data from Survey Question 2 – their written reasons for their attitude rating levels – and participants' Mathematics Autobiographies. Then, I present the results from my analysis of the interview participants' autobiographies, attitude graphs, and interviews, including their self-described turning points. Hence, I am also addressing the attitudes portion of my fourth research question in this chapter: *What types of experiences tend to be turning points in the mathematics attitudes and beliefs of preservice elementary teachers?* I defined *turning points* as any experiences or events that brought about significant change in their attitude toward mathematics.

Whole-Group Survey Question 2 Results

I began analysis for research question 3 by looking at the whole-group responses to Survey Question 2, where participants explained their feelings about mathematics by writing a brief response to "I feel that way because." Recall that Survey Question 1 asked participants to rate their attitude toward mathematics on a Likert scale from 1-5, with 1 representing strongly dislike and 5 representing strongly like. I took all 112 participant responses and sorted them according to the numerical rating they gave to Survey Question 1. This sorting produced one response with rating 1 (Strongly Dislike), fifteen responses with rating 2 (Dislike), 42 responses with rating 3 (Neutral), 40 responses with rating 4 (Like), and fourteen responses with rating 5 (Strongly Like). I then looked for common themes within each rating level, and through an iterative process developed the category codes seen in Table 7.1.

Table 7.1

Coding Scheme developed from analysis of Survey Question 2 responses.

Code	Description
Beliefs about Mathematics	Participant attributes attitude to their views about either the nature of mathematics (e.g., "I like that mathematics always has a right or wrong answer," "Each problem has one answer that can be proven") or as related to their personal experience (e.g., "I never found mathematics very interesting," "I find mathematics is difficult," "Mathematics is like a puzzle for me")
Innate Ability	Participant cites their inborn capability as reason for attitude (e.g., "I am good/bad at it," "It comes easy to me")
Connected to Understanding	Participant cites understanding or comprehension as attributing to their attitude (e.g., "It takes me a while to understand," "It just makes sense")
Course or Topic Dependent	Participant gives particular topics or courses as attributing to their attitude (e.g., "I like all mathematics except calculus," "It depends on the topic we are learning")
Teacher Factors	Participant cites teachers' instructional methods or classroom conduct as attributing to their attitude (e.g., "I had the worst mathematics teacher in high school," "The professor I have now has made mathematics so much fun")

Table 7.1 (cont'd)

Code	Description
General or Nondescript	Participant says nothing specific about experiences (e.g., "I've always had good experiences," "I've not had good experiences with mathematics in the past")
Performance Outcomes	Participants cite their grades or tendency to get the right or wrong answers as attributing to their attitude (e.g., "I get frustrated when I continue to get questions wrong," "I always got bad grades compared to my other classes")
Mathematics Anxiety, Nervousness, Stress	Participants point to mathematics affecting them psychologically in negative affective ways (e.g., "Mathematics always gave me anxiety," "Mathematics has usually caused me some kind of extra stress")
Related to Teaching Mathematics	Participants attribute attitudes to their own experiences as mathematics teachers (e.g., "I like it when I teach others mathematics," "I like learning about how to teach others mathematics"
Test Taking	Participants attribute their attitude to test taking (e.g., "I'm really not good at tests")
Personal Work Ethic	Participants attribute attitude to their own practice or work ethic (e.g., "If you work hard, it will eventually get better," "I used to have bad experiences, but I have come to terms with the fact that I will have to work harder to do well in mathematics")
Parental Influence	Participants cite their parents as influencing their attitude (e.g., "My parents always made mathematics a big part of my life")

Initially, the resulting analysis produced 168 total codes spread across the twelve categories listed in Table 7.1. Some participants listed multiple reasons for their attitudes, and some statements fit into multiple categories.

I also coded each response as "positive," "negative," or "neutral" based on the tone of the participant response. Some positive examples from my participants included "I was always good at mathematics" or "I enjoy the challenge of working through problems and applying knowledge I've gained over the years." Negative examples included "there is too much homework" or "I have never found mathematics very interesting." A neutral response either had something positive and negative in it or showed no emotional tone. Two neutral examples were "I enjoy mathematics when I know exactly what I am doing, but I can get frustrated when I continue to get questions wrong" and "I disliked it in high school but I like it now." Coding for tone was a relatively easy task for those who indicated disliking or liking mathematics, as the context of their numerical rating helped to clarify meaning. For instance, dislikers (ratings 1 and 2) often had a purely negative tone, and strong likers (rating 5) often had a purely positive tone. Likers (rating 4) would include mostly positive tones with a negative tone here or there to justify not having a 5 rating. Neutrals (rating 3) were the most difficult as their statements often showed some mix of positive and negative reasons. On the whole, however, rating for tone was not a difficult task as participants very clearly attached words indicating like or dislike to their responses.

After developing the coding scheme and coding the responses, another mathematics education graduate student reviewed my code assignments, tone ratings, and code descriptions. After reviewing his suggestions and coming to a consensus, eight changes were made which resulted in 175 total coded instances of bases for students' attitudes toward mathematics. Table 7.2 presents the results in order from the most-common to least common, along with a breakdown of how the responses were distributed across the participants' attitude rating.

Table 7.2

Codes allocated to participant responses to Survey Question 2.

Code	**1s**	**2s**	**3s**	**4s**	**5s**	**Total**
Beliefs about Mathematics	0	7	16	21	12	56
Innate Ability	1	6	7	12	5	31
Connected to Understanding	0	4	11	5	0	20
Course or Topic Dependent	0	0	8	8	1	17
Teacher Factors	0	2	6	5	1	14
General or Nondescript	0	1	9	2	0	12
Performance Outcomes	0	2	5	1	0	8
Mathematics Anxiety, Nervousness, Stress	0	4	1	1	0	6
Related to Teaching Mathematics	0	0	2	2	0	4

Table 7.2 (cont'd)

Code	1s	2s	3s	4s	5s	Total
Personal Work Ethic	0	0	1	2	1	4
Test Taking	0	0	2	0	0	2
Parental Influence	0	0	0	0	1	1
Total	1	26	68	59	21	175

The most frequently reported category was *Beliefs about Mathematics*, where participants wrote about their difficulty with mathematics, whether they found mathematics interesting or uninteresting, beliefs about aspects of school mathematics that they liked or did not like, whether they saw mathematics as applicable to their lives or not, or whether they found mathematics fun or boring. Many participants also frequently cited their innate ability, saying things like "It just always came easy to me" or "I am not 'mathematics smart'." Only two participants wrote about understanding in a positive way (e.g., "In general it makes sense why you are doing the operations"), whereas twelve wrote about it in an overtly negative way (e.g., "When I cannot understand a topic or some sort of question it gives me frustration") and six were neutral (e.g., "I struggle with learning the concepts in mathematics. However, when I understand the concepts I get excited"). Nearly all of those who wrote about their feelings about mathematics as dependent on courses or topics were not specific about which courses or topics affected their feelings (e.g., "It depends on the kind of mathematics."), though three participants did specifically point to calculus as having a negative effect on their feelings.

Most of the instances of teacher factors were also vaguely expressed, with participants saying they had either good or bad mathematics teachers. Those who listed specific issues wrote about both instructional aspects of their teaching, like spending extra time with them to make sure they understood material, or on the negative side, that they did not know how to help their students understand. Others wrote about personality traits of their teachers, like their ability to motivate students through words of encouragement or conversely on their tendency to discourage their students.

Only one category produced the development of subcategories, which my colleague also reviewed as part of our collaborative rating work. Table 7.3 gives a list of subcategories that were developed for *Beliefs about Mathematics* as well as their counts within each participant attitude rating level. Because this analysis was not coordinated with the analysis from SQ6 and SQ7, these subcategories were developed separately and hence follow a different naming structure. These subcategories, hence, may contain within them multiple beliefs categories that were distinguished in the tables of Chapter 6. For instance, the subcategory *Beliefs about the Nature of Mathematics* contained beliefs that fell into different Table 6.8 categories, such as *Mathematics is about problem solving* and *Mathematics is black and white; it consists of problems with only one correct answer or solution and one way of getting there*, among others.

Table 7.3

Subcategories developed and frequencies of Beliefs about Mathematics code in participants' responses to Survey Question 2.

Subcode	2s	3s	4s	5s	Total
Character of Mathematics (e.g., fun, interesting, boring)	1	2	9	7	19
Challenge or Difficulty of Mathematics	6	8	2	0	16
Beliefs about the Nature of Mathematics (e.g., like a puzzle, only one right way to solve problems)	0	1	9	5	15
Beliefs about School Mathematics (e.g., It moves too quickly)	0	3	1	0	4
Applicability or Importance of Mathematics	0	2	0	0	2

As Table 7.3 indicates, most participants with “like” ratings (4s and 5s) wrote about their relationship to what they saw as the character of mathematics, describing it as fun, interesting, rewarding, or satisfying. Participants who rated themselves as “dislike” or “neutral” (rating 2 or 3 on the Likert scale) tended to focus on how challenging they found mathematics to be, mostly in negative terms. One neutral participant mentioned enjoying the challenge of working through problems, but the rest in rating levels 2 and 3 discussed how they found their personal struggle with mathematics as a reason for not enjoying it as much. Only one of the *Beliefs about the Nature of Mathematics* statements was negative, where the participant said that in mathematics “You are either right or wrong and there is no in between” and that this aspect of mathematics gives them “frustration.” The remaining beliefs about the nature of mathematics were given as reasons for positive feelings, writing such things like mathematics is a “fascinating language,” that each problem “has one answer that can be proven,” and that there are “many different approaches to a question.”

Those who wrote about school mathematics mostly did so in a negative way, indicating they felt like there was too much homework in mathematics or the pace was too quick. The one positive statement came from someone who enjoyed that she could always check her work and if she had a question in mathematics, she knew someone else probably did as well. Two “strongly like” participants mentioned they enjoyed mathematics because to them it was like a puzzle. As for the *Applicability or Importance of Mathematics* category, one neutral participant did not see mathematics as applicable to her life and the other noted its importance as a positive aspect. The more detailed analysis of relationships found between beliefs about mathematics and attitudes, at least at the level of ratings, was presented previously in Chapter 6.

The tone of the responses to Survey Question 2 (Table 7.4) was very negative for dislikers (ratings 1 and 2) and very positive for likers (ratings 4 and 5).

Table 7.4

Counts of Positive- (Pos), Negative- (Neg), and Neutral- (Neut) toned responses to Survey Question 2, sorted by attitude rating and by category.

Code	1s		2s		3s			4s		5s	
	Pos	Neg	Pos	Neg	Pos	Neut	Neg	Pos	Neg	Pos	Neg
Beliefs about Mathematics	0	0	0	7	4	2	10	18	3	12	0
Innate Ability	0	1	1	5	0	3	4	12	0	4	1
Connected to Understanding	0	0	0	4	0	6	5	2	3	0	0
Course or Topic Dependent	0	0	0	0	0	7	1	8	0	1	0
Teacher Factors	0	0	0	2	2	0	4	4	1	1	0
General or Nondescript	0	0	0	1	0	7	2	2	0	0	0
Performance Outcomes	0	0	0	2	0	3	2	0	1	0	0
Mathematics Anxiety, Nervousness, Stress	0	0	0	4	0	0	1	0	1	0	0
Related to Teaching Mathematics	0	0	0	0	1	1	0	2	0	0	0
Personal Work Ethic	0	0	0	0	0	1	0	2	0	1	0
Test Taking	0	0	0	0	0	0	2	0	0	0	0
Parental Influence	0	0	0	0	0	0	0	0	0	1	0
Total	0	1	1	25	7	30	31	50	9	20	1

The only reason given by the strong disliker (rating 1) was a negative one ("I have never been good at it"). Only one positive reason was given in the level 2 rating (dislike), where, in part of their response, a participant wrote about their innate ability, "I know I am capable of doing mathematics, and when I do it I enjoy it." The rest of their response, however, focused on their engagement with other subjects, the anxiety that mathematics causes, and how long it takes them to understand mathematics. There was also only one negative reason given by strong likers (rating 5), where a participant wrote that mathematics had not come easily for them. For likers (rating 4), nine of the 59 responses had a negative tone, with only two categories – *Connected to Understanding* and *Beliefs about Mathematics* – having more than one negative response. Two participants wrote that they get frustrated when they do not understand a topic and another simply wrote that sometimes they don't understand it. One participant wrote that they thought there was too much homework in mathematics, where another felt like mathematics was the only subject in which they struggle.

Neutral participants (rating 3) tended to give neutral responses. Most either gave both positive and negative reasons for their feelings about mathematics or generally expressed a neutral tone. However, eleven of the 42 in this category gave exclusively negative-toned justifications for their "neutral" feelings about mathematics while no participants gave exclusively positive-toned justifications. Also, of the 68 reasons given by those in the neutral category, nearly half (n=31) had a negative tone, seven had a positive tone, and 30 had a neutral tone (e.g., they like some topics but not others, felt average in their capability). The higher number of responses with a purely negative tone relative to those with a purely positive tone aligns with the results of chapter 5, where some participants who gave a neutral rating of 3 seemed to reflect upon having more negative feelings toward mathematics than neutral.

The majority of the negative factors for the neutrals were spread across the categories *Beliefs about Mathematics* (*n*=10), *Connected to Understanding* (*n*=5), *Innate Ability* (*n*=4), and *Teacher Factors* (*n*=4). Only three categories included any purely-positive factors: *Beliefs about Mathematics* (*n*=4), *Teacher Factors* (*n*=2), and *Related to Teaching Mathematics* (*n*=1). Categories registering the most neutral comments – where participants mentioned both good and bad aspects of their experiences with mathematics – were *Course or Topic Dependent* (*n*=7), *General or Nondescript* (*n*=7), and *Connected to Understanding* (*n*=6) had the most neutral comments. The first in that listing was somewhat predictable in that it seemed natural for participants to enjoy some topics or courses in mathematics and dislike others. Likewise with *Connected to Understanding*, they predictably liked it when they understood the mathematics they were learning and disliked it when they did not understand.

Whole-Group Autobiographical Results

After analyzing the results from Survey Question 2, I then turned to analyze similar statements in the autobiographies—those that addressed the nature and source of their attitudes. With 112 total participants, I could not feasibly code all the data, so I selected a random sample of 50% of the participants within each attitude rating level. This resulted in one participant at level 1 (from N = 1), eight at level 2 (from N = 15), 21 at level 3 (from N = 42), twenty at level 4 (from N = 40), and seven at level 5 (from N = 14).

Rather than try to assess how experiences might have changed participants' attitudes or beliefs – assessments that seemed very difficult to determine and justify – I analyzed all experiences or statements they wrote that seemed to have a positive or negative assessment. I highlighted each statement or experience they mentioned related to mathematics in their autobiography and coded them using the coding scheme in Table 7.1 above. New categories emerged for statements that did not fit the existing categories from the prior analysis. These are listed in Table 7.5 below. The *General or Nondescript* category in Table 7.1 was not utilized in this analysis as participants were more detailed in describing their experiences in their autobiographies. All experiences were also coded for their positive or negative tone, so there were no neutral tones in this analysis. When participants gave a statement that carried both a positive and negative tone within a category – which would have been considered neutral in my Survey Question 2 analysis – I split the statement into two, yielding one positive and one negative experience or statement.

Table 7.5

New experience codes developed through analysis of autobiographies.

Code	Description
Peer Comparison or Influence	Participants attribute attitude as resulting from a comparison to their classmates or peers in their grade level or age level, or attribute it to words spoken by peers or classmates (e.g., My friends were very good at mathematics too, so they made me want to be just as good as them.)
Tutoring	Participants attribute attitude to some aspect of tutorials they received from others. (e.g., “Mathnasium was beyond amazing. My tutor was individualized to me and solely focused on getting the work done, but still making sure I understood the concepts.”)
School or Classroom Factors	This includes things like switching schools, having to switch classrooms, distractions resulting from the physical classroom (e.g., too many windows to look out of), and the like. (e.g., “I was in a whole different town, in a new school and mathematics started to freak me out again”)
Speed or Pace of Learning	Participants attribute attitude to the pace of learning mathematics as too fast or too slow for them. (e.g., “my mathematics moved at a quicker pace, and I definitely struggled a bit to keep up”)
Family or Personal Factor	Something happening in the participant's personal life (e.g., with their health, family, relationship) affected their feelings or performance in mathematics (e.g., “When I moved back to the states in 9th grade I wasn’t able to go back on the advanced track so it made me resent mathematics because it became a constant reminder of where I could’ve been if I hadn’t been forced to move to Canada with my mom and her new husband.”)

The analysis yielded 501 statements that were placed into the sixteen coding categories—eleven from Table 7.1 and five from Table 7.5. As before, a portion of those 501 statements matched more than one category and were thus double-coded. Results indicated that teacher factors were the most frequently discussed experience in autobiographies, followed closely by statements about their grades or performance outcomes in classes or on exams (Table 7.6).

Table 7.6

Codes allocated to mathematical experiences and statements from participants' autobiographies.

Code	**1s**	**2s**	**3s**	**4s**	**5s**	**Total**
Teacher Factors	0	28	39	35	17	119
Performance Outcomes	2	6	40	43	9	100
Course or Topic Dependent	0	5	23	33	6	67
Innate Ability	1	4	14	27	1	47
Beliefs about Mathematics	1	4	18	14	6	43
Connected to Understanding	0	4	16	10	1	31
Peer Comparison or Influence	1	3	14	11	1	30
Test Taking	1	3	6	5	3	18
School or Classroom Factor	0	3	1	7	1	12
Personal Work Ethic	0	0	5	6	0	11
Related to Teaching Mathematics	0	0	2	3	3	8
Tutoring	0	1	3	1	0	5
Speed or Pace of Learning	0	0	3	1	0	4
Parental Influence	0	0	1	1	1	3
Family or Personal Factor	0	0	1	1	0	2
Mathematics Anxiety, Nervousness, Stress	0	0	1	0	0	1
Total	6	61	187	198	49	501

Table 7.6 provides a different view of experiences than Table 7.2, which contained the reasons participants gave for their attitude ratings. This table, instead, contains all of the experiences they cited in their autobiographies, which were geared specifically toward their K-12 school experiences. Hence, it makes sense that their focus here would be more on teachers and

grades than it was previously. *Teacher factors* ranged from comments about having or not having teachers help them with their understanding through good/poor instruction to having teachers who were friendly and personable or, conversely, discouraging and mean. Those who disliked mathematics (ratings 1 and 2) discussed teaching factors in nearly half of their statements in their autobiographies, whereas no other category generated more than eight statements between the dislikers. Those who had said they were more neutral or liked mathematics (ratings 3, 4, and 5) were more evenly split between teacher factors and other categories. Many of the teacher factors were more generically stated, referencing having their “favorite teacher” or being affected by “poor teaching” without going into detail. Those who included more detail about negative teacher experiences wrote about instructional factors such as being told they had to solve problems a certain way, had teachers who were “horrible at explaining concepts,” being taught in a lecture style, having teachers be late to class and slow at grading, or being taught too quickly. Negative teacher personality factors included having teachers show a lack of enthusiasm, being unkind or condescending, appearing to favor the “smarter kids,” getting mad and yelling at students for incorrectly answering a question, and making participants feel “dumb and inferior” to their peers.

Positive teacher factors that focused on instructional issues included taking time to show various ways to find a solution to a problem, encouraging students to find their own ways to figure out problems, having students work in groups and have discussions about mathematics, using diagrams to help students understand concepts, teaching at an appropriate pace for students’ learning abilities, and having good classroom discipline techniques. Teacher personality factors included encouraging their students, showing enthusiasm about mathematics, having a fun and positive attitude, and taking special interest in their students’ lives. Some teacher factors, like using competitions and games or having a strict discipline style, were described by some participants positively and others negatively.

Performance outcome statements often referred to a grade in a class or on exams or homework (e.g., “I barely passed” or “I did well in that class”). Other performance outcomes included comments about moving up to an accelerated class due to their performance or failing a placement exam and having to remain in a standard-level course. A secondary outcome that was often mentioned was how doing poorly or doing well affected their confidence in negative and positive ways, respectfully. Some students mentioned their successes as “rewarding,” while others said their failures made them feel they were not good at mathematics or dread going to their mathematics class.

Within the *Course or Topic Dependent* category, a wide range of topics and subjects were discussed. The likers (ratings 4 and 5) had more positive comments about algebra, and all negative comments about geometry and calculus. Conversely, those in rating levels 2 (dislike) and 3 (neutral) discussed algebra almost exclusively negatively and geometry quite positively (and had no comments on calculus). Across all attitude ratings, participants generally mentioned their experiences in their college elementary mathematics content course in a positive way, with only one negative statement (out of seven total) where the participant discussed not liking having to explain their mathematical thinking. Precalculus and Trigonometry had a near-even split between positive (n=3) and negative (n=4) comments. A number of participants also recalled negative experiences with their multiplication facts and times tables; five of the seven participants who wrote about it indicated struggles or bad memories.

Peer Comparison, a new category that emerged in the autobiography analysis stage, was surprisingly prominent – having not been mentioned in any of their Survey Question 2 responses.

Overall, the tone in this category was overwhelmingly negative, with only five of the 30 coded responses mentioning positive experiences or statements about their peers. Participants who commented positively mentioned experiences like being one of the quickest kids in their class and having a positive relationship with their peers. On the negative side, the most commonly cited was being embarrassed by being left behind their peers who moved to higher-level mathematics courses while they did not. They also mentioned noticing they were the slowest ones on their tests, feeling like their peers understood while they did not, or having peers overtly tell them discouraging words that hurt their confidence in mathematics.

Table 7.7 shows all the positive and negative statements given by participants within each attitude rating and within each category.

Table 7.7

Counts of Positive- (Pos) and Negative- (Neg) toned statements made by participants in their autobiographies, sorted by attitude rating and by category.

Code	**1s**		**2s**		**3s**		**4s**		**5s**	
	Pos	**Neg**	**Pos**	**Neg**	**Pos**	**Neg**	**Pos**	**Neg**	**Pos**	**Neg**
Teacher Factors	0	0	12	16	19	20	23	12	8	9
Performance Outcomes	0	2	4	2	17	23	30	13	7	2
Course or Topic Dependent	0	0	2	3	10	13	16	17	1	5
Innate Ability	0	1	0	4	4	10	16	11	1	0
Beliefs about Mathematics	0	1	1	3	6	12	11	3	5	1
Connected to Understanding	0	0	2	2	6	10	7	3	0	1
Peer Comparison or Influence	0	1	0	3	1	13	4	7	0	1
Test Taking	0	1	1	2	1	5	0	5	1	2
School or Classroom Factor	0	0	1	2	0	1	1	6	0	1

Table 7.7 (cont'd)

Code	**1s**		**2s**		**3s**		**4s**		**5s**	
	Pos	**Neg**	**Pos**	**Neg**	**Pos**	**Neg**	**Pos**	**Neg**	**Pos**	**Neg**
Personal Work Ethic	0	0	0	0	3	2	6	0	0	0
Related to Teaching Mathematics	0	0	0	0	2	0	3	0	3	0
Tutoring	0	0	1	0	3	0	1	0	0	0
Speed or Pace of Learning	0	0	0	0	0	3	0	1	0	0
Parental Influence	0	0	0	0	0	1	1	0	0	1
Family or Personal Factor	0	0	0	0	0	1	0	1	0	0
Mathematics Anxiety, Nervousness, Stress	0	0	0	0	0	1	0	0	0	0
Total	0	6	24	37	72	115	119	79	26	23

The lone participant with a strongly dislike attitude (rating 1) gave only negative recollections of her experiences with mathematics in her autobiography. Overall, the dislikers (rating 2) and neutrals (rating 3) also had more negative experiences to share than positive in their recalled history with mathematics. Among the dislikers, no category seemed to be much more negatively skewed than any other, though there were categories with only negative recollections, led by *Innate Ability* and *Peer Comparison or Influence*. The same two categories were particularly negatively skewed for the neutrals as well. As for the likers and strong likers (ratings 4 and 5), while most categories were positively skewed, *Teacher Factors* was not for strong likers. Generally, likers and strong likers had positive views of their innate abilities and held positive beliefs about mathematics. All participants who wrote about their experiences with tutors and teaching others mathematics did so favorably. As mentioned previously, experiences with peers and making were mostly negative, as were experiences with test-taking and the pace of learning in their courses (e.g., too slow or too fast).

Interview Participant Experiences

Interviews began with participants re-reading their autobiographies and highlighting the moments they found affected their feelings about mathematics. I carried out a similar analysis as the whole-group, but only for the participant-highlighted moments. Statements were assigned positive and negative codes based on the context of the autobiographies and/or location of event on the attitude graph. There was one neutral comment – highlighted by Participant 8 – where she described her first recalled experience with numbers as “Not great, not poor, but somewhere in a gray area that depended on many things.” Table 7.8 shows the results of coding the interviewees’ highlighted statements from their autobiographies.

Table 7.8

Codes allocated to interviewees’ highlighted statements from their autobiographies.

Code	**1s**	**2s**	**3s**	**4s**	**5s**	**Total**
Teacher Factors	1	9	5	4	6	25
Performance Outcomes	2	10	4	3	5	24
Peer Comparison or Influence	1	4	3	2	1	11
Course or Topic Dependent	0	3	5	1	2	11
Personal Work Ethic	0	1	2	1	1	5
Tutoring	0	1	2	0	1	4
Parental Influence	0	1	0	1	2	4
Test Taking	0	1	0	0	3	4
School or Classroom Factor	0	1	1	1	1	4
Beliefs about Mathematics	0	0	2	2	0	4
Connected to Understanding	0	1	2	0	0	3
Family or Personal Factor	0	3	0	0	0	3
Innate Ability	0	0	0	2	0	2

Table 7.8 (cont'd)

Code	1s	2s	3s	4s	5s	Total
Related to Teaching Mathematics	0	0	0	1	0	1
Speed or Pace of Learning	0	0	0	1	0	1
Total	4	35	26	19	22	106

As seen in Table 7.8, the interviewees' selection of the events they recalled as most-influential on their attitudes toward mathematics followed the pattern from Table 7.6 of the whole-group autobiographies with *Teacher Factors* and *Performance Outcomes* reported most often. Peer performance was ranked a little higher with the interviewees than in the whole-group sample, and even received more counts from the dislikers in this small sample than in the larger sample. Courses and topics were mentioned relatively similarly (about half as much as the higher groups), but innate ability in this sample was barely mentioned despite its popularity in the whole-group results shown in Table 7.6.

Positive teacher factors cited by the interviewees included being accommodating and understanding of students, being available for help, focused on helping students understand the "why" of the mathematics they were learning, and making class fun (e.g., bringing in pie on pi-day). Negative teacher factors included lacking enthusiasm, answering questions with more questions, being unorganized, showing hostility, demeaning students, and thinking their students incapable of certain achievement. Both positive and negative performance outcomes included grades, passing or not passing state or entrance exams, and achieving or not achieving a promotion to a more advanced or honors-level course.

Interviewees mentioned their peers or particular mathematical topics about half as often as those top two categories. One interviewee wrote about how she kept hearing from her peers that mathematics was hard and awful, so she believed that stigma throughout middle school.

Three participants mentioned feeling dumb because their peers were in advanced mathematics, and they were not. One noticed she was always the last to turn in her tests. On the positive side, one participant gained confidence from moving up to an advanced class while her friends did not. Another gained confidence from tutoring her friends, and a third felt comradery with her peers by finding out that many of her classmates were also struggling with mathematics. All five positive course or topic statements cited experiences in the *Mathematics for Elementary Teachers* course, where all other content areas or topics (multiplication, algebra, geometry, calculus) were recalled negatively except for the one neutral statement about counting mentioned earlier. Interview participants focused less on their innate ability, understanding of the mathematics, and beliefs about mathematics.

Table 7.9 gives the frequencies for positive, negative, and neutral statements or experiences highlighted by my interview participants with each category.

Table 7.9

Frequencies of Positive- (Pos), Negative- (Neg), and Neutral- (Neut) toned responses in interviewee autobiographies, sorted by attitude rating and by category.

Code	1s		2s			3s		4s		5s	
	Pos	Neg	Pos	Neut	Neg	Pos	Neg	Pos	Neg	Pos	Neg
Teacher Factors	0	1	3	0	6	3	2	2	2	2	4
Performance Outcomes	0	2	2	0	8	2	2	3	0	2	3
Peer Comparison or Influence	0	1	1	0	3	2	1	1	1	0	1
Course or Topic Dependent	0	0	2	1	0	2	3	0	1	1	1
Personal Work Ethic	0	0	0	0	1	1	1	1	0	1	0
Tutoring	0	0	1	0	0	1	1	0	0	1	0
Parental Influence	0	0	0	0	1	0	0	1	0	1	1
Test Taking	0	0	0	0	1	0	0	0	0	0	3

Table 7.9 (cont'd)

Code	1s		2s			3s		4s		5s	
	Pos	**Neg**	**Pos**	**Neut**	**Neg**	**Pos**	**Neg**	**Pos**	**Neg**	**Pos**	**Neg**
School or Classroom Factor	0	0	0	0	1	0	1	0	1	0	1
Beliefs about Mathematics	0	0	0	0	0	0	2	0	2	0	0
Connected to Understanding	0	0	1	0	0	1	1	0	0	0	0
Family or Personal Factor	0	0	1	0	2	0	0	0	0	0	0
Innate Ability	0	0	0	0	0	0	0	1	1	0	0
Related to Teaching Mathematics	0	0	0	0	0	0	0	1	0	0	0
Speed or Pace of Learning	0	0	0	0	0	0	0	0	1	0	0
Total	0	4	11	1	23	12	14	10	9	8	14

While the strongly dislikers, dislikers, and neutrals follow a more expected pattern in their positive and negative ratings – dislikers highlighted more negative experiences and neutrals were more evenly split – the likers and strongly likers were more surprising in what they highlighted. The likers highlighted only one more positive experience than negative, and the strongly likers highlighted more negative aspects of their experience with mathematics than positive. While initially this may seem contradictory, it is worth noting that the prompt for their highlighting was to indicate moments that had an effect on their attitude. Hence, for those with mostly positive experiences, they may only have thought about those moments that were less so, and in the case of the strongly likers, the focus was mostly on teachers, grades, and tests. Anyone who likes any subject area could have a particularly bad teacher, grade that was below expectations, or a few bad exams. Yet, it is worth noting the trend that mathematics likers (including strongly likers) in both whole-group and interview analyses reported a significant number of negative experiences, signifying that no one seems to be completely exempt from negative experiences with mathematics.

Teacher Factors, *Performance Outcomes,* and *Peer Comparison or Influence* categories contained the most negative remarks among interviewees who indicated disliking mathematics. As mentioned above, negative teacher factors included both personal factors (e.g., lacking enthusiasm, showing hostility) and instructional factors (e.g., answering questions with more questions, being unorganized). Negative performance outcome remarks were about poor grades, not passing certain exams, and not achieving a promotion to a more advanced course. Negative peer comparison remarks included hearing that mathematics awful, feeling “dumb” because friends were in advanced mathematics (and they were not), and noticing being the last to turn in tests.

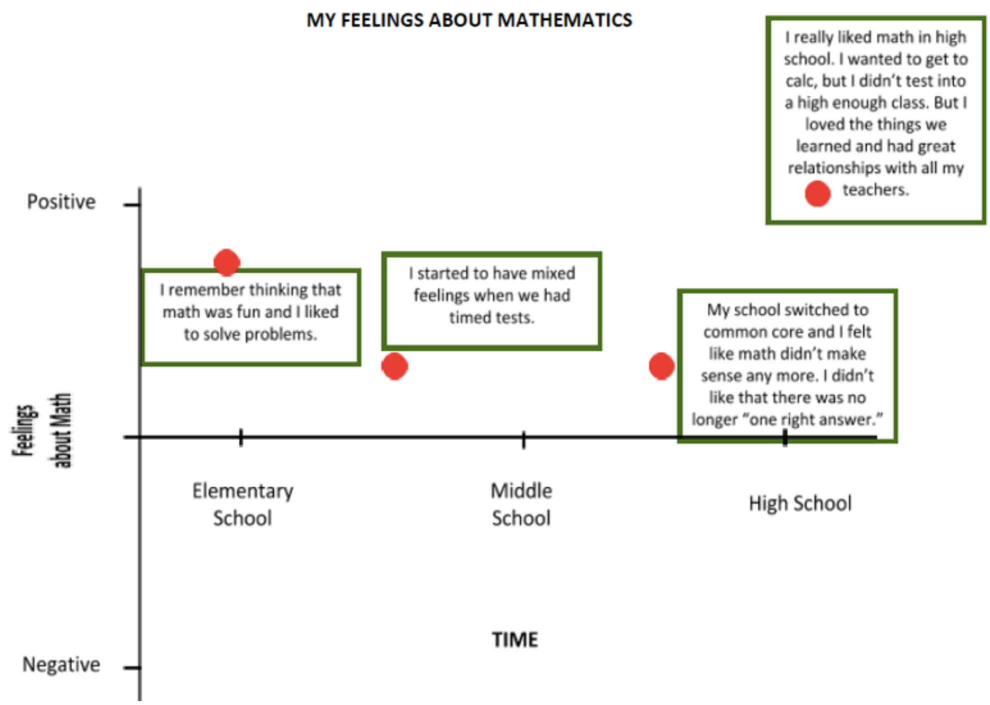
Highlighted experiences across all attitude rating levels about *Test Taking*, *School or Classroom Factor*, and *Beliefs about Mathematics* were all negative. The first two are not unsurprising as they both are mostly out of the control of the participant. As for beliefs, two participants viewed mathematics as boring, one expressed their belief that if you were not at the advanced level it meant you were bad at it, and the fourth expressed her belief that at one point she viewed mathematics as awful and hard. *Tutoring* was proportionately the most positive category with three out of four participants indicating having had positive experiences with their tutors.

Annotated Attitude Graph Results

Once the interviewees finished highlighting the experiences they saw most impactful on their attitudes toward mathematics in their autobiographies, I asked them to complete their attitude graphs. Participants plotted their attitudes toward mathematics over time on the graph, and they gave reasoning for each plotted point in a textbox next to the point on the graph. The attitude graph from Participant 5 can be seen below in Figure 7.1 as an example of what a completed attitude graph looks like.

Figure 7.1

Complete Attitude Graph from Participant 5.



The attitude graphs (see **APPENDIX F**) provided a useful representation to see how participants perceived the events the graphed changed their feelings about mathematics. The task, by nature, foregrounded time and change over time in an even more explicit way than the autobiography did. In this part of the analysis, I used their graphs to not only learn about what events were most important to participants, but also when they happened (i.e., elementary, middle, high school, or college). I also could see just how influential they perceived those events to be (e.g., drastic changes from positive to negative, minor dips or raises in attitude). After the attitude graph activity I asked participants about specific events that needed clarification as well as which they saw to be *turning points* – the experiences or events that brought about significant change in their attitudes or beliefs. Each turning point was classified according to the codes found in Table 7.10 below. As mentioned in Chapter 4, I included classifications in which no turning points happened as well (Smooth Track, Consistently Frustrated) as prior research has indicated the possibility of people having such experiences with mathematics (see McCulloch et al., 2013).

Table 7.10

Framework for Characterizing Participants' K-12 Mathematics Experiences

Experience Type	**Description**
Smooth Track	PSTs had no negative mathematics experiences
Minor Setback	PSTs experienced one or two negative mathematics experiences, but they were not detrimental to their overall attitude
Roller Coaster	PSTs have both positive and negative experiences throughout schooling
Consistently Frustrated	PSTs have primarily negative early experiences and accepted them as foreshadowing a lifelong mathematics weakness
Snowballing	PSTs enjoy mathematics early, but each successive experience seems to lower their attitude and grow a distaste for mathematics.
Positive Turning Point	PSTs have strongly negative memories of mathematics up until a particular point (turning point), in which one specific positive experience resulted in a more positive attitude toward mathematics or a realization that it is possible to succeed at and enjoy mathematics
Negative Turning Point	PSTs have positive memories of mathematics up until a particular point (a turning point) in which one specific experience resulted in a more negative attitude toward mathematics

(adapted from McCulloch et al., 2013, p. 383)

As in Chapter 5, I will present the results by rating level, and since the shapes of the graphs were discussed in relationship to attitude already in Chapter 5, I will focus this report on the experiences participants annotated on their graphs as bringing about change in attitudes. Participants most commonly annotated their graphs with experiences related to their teachers, and such experiences with teachers, along with performance outcomes, were most commonly associated with positive or negative turning points across all rating levels. Also, the results below further the findings from Chapter 5 that attitudes are not fixed by attaching the reasons for such attitude changes. Lastly, the following sections highlight how recollections of similarly-described experiences can affect people quite differently, with some influenced by positive or negative experiences long-term whereas others seem to move on relatively quickly from the positive or negative feelings of such experiences.

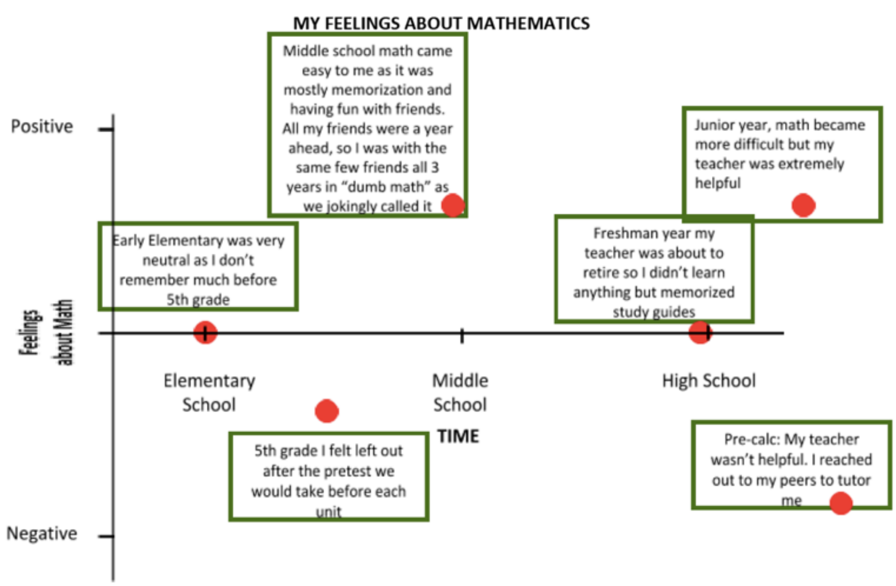
Strongly Dislike (*n*= 1). Participant 1 had a steadily declining graph. Her earliest plotted memory indicated liking mathematics in elementary school, despite finishing last on her "times test," because she was not punished for being slower. Each subsequent experience she wrote on the graph described or contributed to her declining attitude toward mathematics over time. The experiences annotated on her graph focused heavily on her scores in mathematics. She first indicated low mathematics benchmark scores as her first experience lowering her feelings about mathematics. In middle school, she indicated teachers giving up on her "when getting low scores." Her last two data points did not cite specific experiences but indicated that in high school she gave up trying and no longer cared about learning mathematics. When I asked her for further clarification in the interview, she said that it was due to consistent low scores on tests and exams, and she felt that teachers gave up on her.

When I prompted her about whether she saw any of her experiences as turning points in her attitude, Participant 1 indicated that she did not recall a specific event. She said, “I think it was just like continuous low grades, me not getting any better. And then when, um, middle school, when teachers were giving up on me, like they wouldn't help me out anymore.” Because she initially liked mathematics and was informed by the consistency of her negative experiences rather than by one or a few major events, I classified her as *Snowballing*. When I asked her whether teachers or grades had been most influential, she said, “I think my grades were a big part of, um, my experience with mathematics just because it would lower my self-esteem each time I did get one, a low grade, I mean, so like that would make me not want to do it.” She clarified that teachers (in general) just would not offer help, which reinforced her low self-esteem and made her feel like a “lost cause.”

Dislike (*n*= 4). As mentioned in Chapter 5, all four participants with an attitude rating of 2 made graphs with some ups and downs (see example in Figure 7.2 below)– there was no steady

Figure 7.2

Attitude Graph for Participant 10



decline or steady incline throughout. Participants 6, 8, and 10 recalled beginning elementary school at either a neutral place or holding positive feelings about mathematics. Participant 7 said her earliest memory of feeling anything toward mathematics was her negative experience in fifth grade, implying she also may have held a neutral feeling toward mathematics prior to that point.

Both Participants 7 and 10 recalled their first negative experience happening in fifth grade, and both were informed by similar experiences with ability grouping by the teachers. Participant 7 felt that being left out of the advanced section of mathematics (by teacher's choice) meant she was "not good at mathematics" and Participant 10 felt "left out" when classmates who performed well on mathematics pretests went to sit in the hall while she had to stay in the classroom with those who did not perform as well. Participant 6 likewise reported her first negative experience in elementary school (third grade) with a teacher, but not because of ability grouping. Her teacher would scream and yell at students for getting problems wrong, which Participant 6 said gave her "mathematics anxiety" from that point onward. She unfortunately had the same teacher in middle school that brought her feelings about mathematics right back into the negative after positive experiences in-between.

Participants 7 and 10 were more heavily affected by their teachers' instruction and decisions than other factors in general, with each indicating on their graphs other teacher factors affecting their attitudes three times after those fifth-grade experiences. Both participants reflected on good experiences with teachers who spent the effort to help them with mathematics outside of class and who took a personal interest in them as people. Negative teacher experiences included instructional issues (Participant 7) and personality issues (both Participants). Participant 7 recalled having a secondary teacher who was very intelligent and knew mathematics but did not know how to help others learn it and an elementary mathematics content course instructor who was disorganized and confusing in her instruction. Participant 10 recalled a secondary teacher who was near retirement and seemed to stop caring about his job or students' learning and Participant 7 recalled a secondary teacher who had great relationships with advanced students but was "hostile, impatient, and demeaning toward his 'regular' mathematics students."

Unlike the other three, Participant 8 did not have any real dips in her feelings about mathematics until the end of middle school. Though she did draw a decline in her attitude toward mathematics on her graph for part of sixth grade, she attributed that to not being able to see well – a personal, physical trait – rather than to mathematics itself or to any learning- or understanding-related factors. Once she got glasses, she felt better about her learning and, hence, her attitude was right back up. Though she showed some positive moments in the graph that she attributed to her achievement in her classes after middle school, I want to note that she differed from other participants in that the location of her points on her graph did not seem to accurately reflect her attitude toward mathematics at the time. In both her autobiography and interview, she confirmed an underlying persistent negative attitude toward mathematics despite the achievement and positive position on the graph. So, despite graphing those positive feelings, the story she told in her autobiography and interview painted a picture of never feeling she belonged in mathematics. Her last point in the graph – which she attributed to finally not having to take any more mathematics classes – confirms such feelings by being the most positive "mathematics experience" she noted.

The cause of such negative feelings for Participant 8, despite reporting consistent success (high grades) in mathematics, was due to her negative turning point after seventh grade. She had gotten the second-highest grade in her class that year, which she said was a 98%. She expected to move up with the two boys who achieved similarly, with a 99% and a 98%. The boys, however, moved up to algebra and she was told to take pre-algebra a second time. She saw this as a message that she must not belong, saying in her autobiography that because of this experience "mathematics is a symbol to me of the real gender-based stereotypes that our society holds." She got As in all of her mathematics courses, but she dreaded every course. I classified her as having a *Negative Turning Point*. Despite some ups and downs on her graph, she confirmed always dreading mathematics and because of that one event, despite her successes, she never felt she belonged or was "mathematics smart."

Like Participant 8, Participant 7 was classified as having one *Negative Turning Point*. In her interview, Participant 7 emphasized the fifth grade moment described above as the moment she saw as her only major turning point in her attitude toward mathematics. While she indicated having a good teacher in sixth grade, that was an outlier to the rest of her story. She said that her mathematics teachers past sixth grade consistently reinforced her negative feelings. She also indicated her poor mathematics performance on the ACT and SAT, despite spending time with a tutor and hard work, left her "very frustrated and intensified [her] dislike for mathematics."

Both Participants 6 and 10 were assigned *Roller Coaster* classifications for their turning points. Participant 6 said her first turning point was the third-grade experience with the teacher who would scream and yell at her students for doing problems or tasks incorrectly. She identified having that same teacher in middle school as another turning point, returning her to negative feelings after having built back up to positive since her third-grade experience. Following mostly negative experiences in high school, Participant 6 identified her ability to relate to the content in her elementary mathematics content courses as a positive turning point. For her turning points, Participant 10 said she experienced a number and felt like each depended on the teacher. She identified not enjoying her freshman year teacher as a negative turning point, the help of her junior-year teacher – despite struggling with the mathematics – as a positive turning point, and her senior-year precalculus teaching style as her final negative turning point.

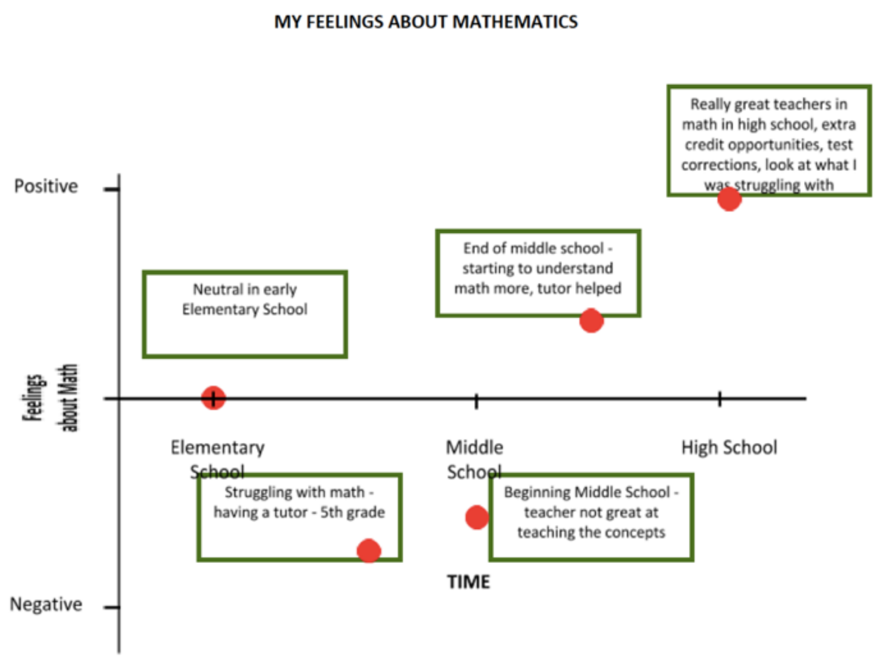
Neutral (*n*= 3). All "neutral" participants produced graphs with distinctly different shapes. Participant 12's graph indicated remaining at a very positive attitude throughout elementary and middle school and ending at a negative attitude in high school. Participant 13's graph was like an upward-facing parabola, with the minimum occurring in elementary school before continually going up throughout the rest of her recalled experiences. Participant 14 had a linear-shaped graph with a negative slope – it began very positive and ended very negative – and was a very similar graph to that of Participant 1.

Both Participants 12 and 14 recalled positive feelings toward mathematics in elementary school and ended with negative feelings in high school. Both indicated that elementary mathematics came pretty easily to them, and they were generally successful in it. Though Participant 14 indicated a lower plotted point for middle school mathematics, she still said she "didn't mind it," and like Participant 12, her high school experiences moved her feelings toward genuine dislike of mathematics. Participant 12's dislike in high school stemmed from her Algebra II teacher who refused to help her in the ways she desired, often responding to her inquiries with questions rather than helping her understand mathematics or trying to help her understand her mistakes. Participant 14 did not understand Algebra I, saying she "grew an immediate dislike for all of the letters that I was seeing in the equations." Both participants indicated their dislike for mathematics only grew worse later in high school when they had to take subsequent mathematics courses that built on the ideas they should have learned in these courses in which they struggled.

Participant 13 seemed to have an opposite experience in terms of feelings toward mathematics over time (see Figure 7.3). The lowest point of her relationship with mathematics occurred in elementary school (fifth grade) and her highest point occurred in high school. She indicated she did fine in early elementary school, but she really struggled in fifth grade, had to get a tutor and simply found mathematics “not fun.” Toward the end of middle school, she felt she was finally beginning to understand mathematical concepts better, and in high school “really great teachers” and some grade-boosting opportunities (i.e., extra credit, test corrections) brought her to a good place in her relationship with mathematics.

Figure 7.3

Attitude Graph for Participant 13.



All three neutral participants fit different turning point classifications. Participant 12 was classified as having a *Negative Turning Point*, based on her graph (See **APPENDIX F**) that showed a sustained highly-positive attitude until the last point where she indicates her negative experience in Algebra II. She said this experience was her turning point because “I always enjoyed mathematics classes till then. And then all of a sudden, mathematics just made me nervous. Like I did not want to go to my mathematics classes at all after that experience." After that turning point, she said she did not understand the content grounded on the ideas she should have learned in Algebra II and, hence, she sustained her negative attitude.

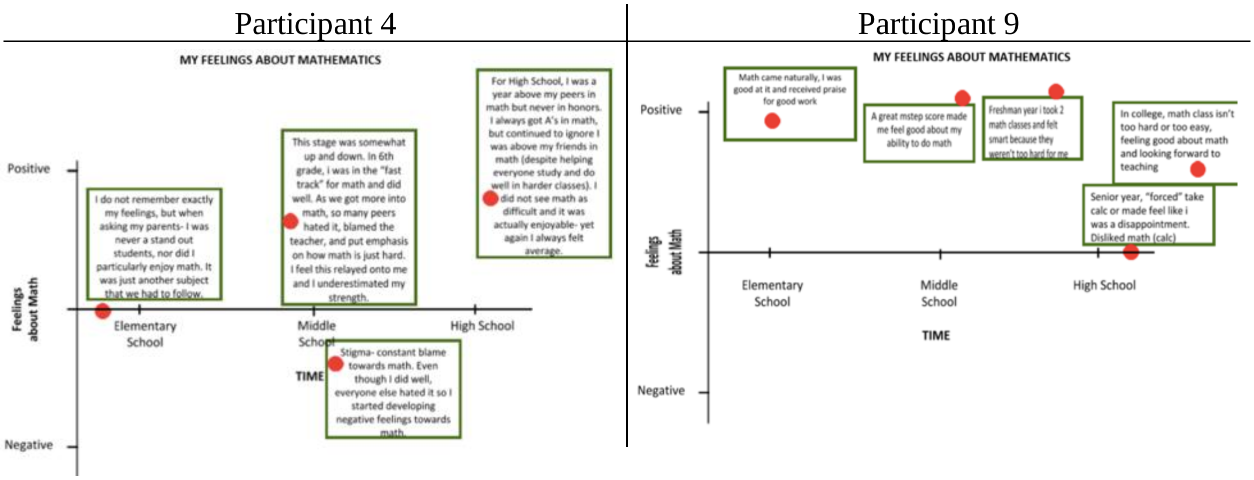
Participant 13 was classified as *Roller Coaster*. She said she had two turning points – a negative one in fifth grade due to her struggles and need for a tutor and a positive one in ninth grade when she felt her teachers finally knew how to teach concepts and offered their help. She also mentioned in her interview that her feelings toward mathematics often depended on the kind of mathematics she was taking. For instance, she found mathematics in her college experience "tedious," but she liked all the concepts from algebra in high school. Hence, she seems to base her attitude mostly on the mathematics she was learning and her understanding of it, rather than the circumstances around that learning (e.g., the teacher, classroom).

Participant 14 was classified as *Snowballing.* Like Participant 1, she began with a positive attitude in elementary school but subsequent events in her schooling lowered it. Those events were diverse. She indicated not liking a summer mathematics program her mom made her complete when she would rather have been "having fun." Then in middle school, she felt not moving to advanced-level classes made her "look dumb." Her negative experience after middle school was with Algebra I, a brief rise in attitude during geometry (enjoying both the subject matter and her teacher), followed by "hatred for mathematics" in 11^{th} and 12^{th} grade where she realized her lack of understanding of Algebra I was affecting her ability to understand Algebra II and Pre-calculus.

Like (*n*= 3). Participants 4 and 9 produced similar graphs as seen in Figure 7.4 below. Both sustained positive attitudes toward mathematics with only minor negative changes during

Figure 7.4

Participants 4 and 9's attitude graphs.



the course of their K-12 experiences with mathematics. For Participant 4, a slight dip in her attitude happened in middle school when she got caught up with her peers in accepting what she called the societal "stigma" that mathematics is hard and horrible and hence is itself a problem. She said that because everyone else hated it, she felt she should dislike it, too. As she matured, however, she realized she enjoyed mathematics and helping others in mathematics despite the message she received that she should not, and her attitude went back to being positive in high school.

Participant 9 had her negative dip late in high school when she had to take calculus. She confirmed her Survey Question 2 response where she said she liked all mathematics except calculus both in her graph and in her interview. She said calculus nearly ruined her love for mathematics, but her college experiences in her elementary mathematics content courses were bringing it back. She said there was just something about calculus she could not grasp, and it was her lack of understanding – not her teacher or other factors – that frustrated her the most.

Participant 11 plotted a graph that decreased continually through early high school before oscillating between positive and negative for the rest of the graph. Her initial feelings were positive, but after second grade she said she felt mathematics no longer challenged her and she became bored with the subject. Her second grade teacher did a wonderful job of challenging her – specifically letting her learn mathematics with the fifth graders when it was their mathematics portion of the day. Since that time, however, she felt that mathematics became repetitive, and she had to sit through lessons that were too long because she understood the concept the first time they were discussed.

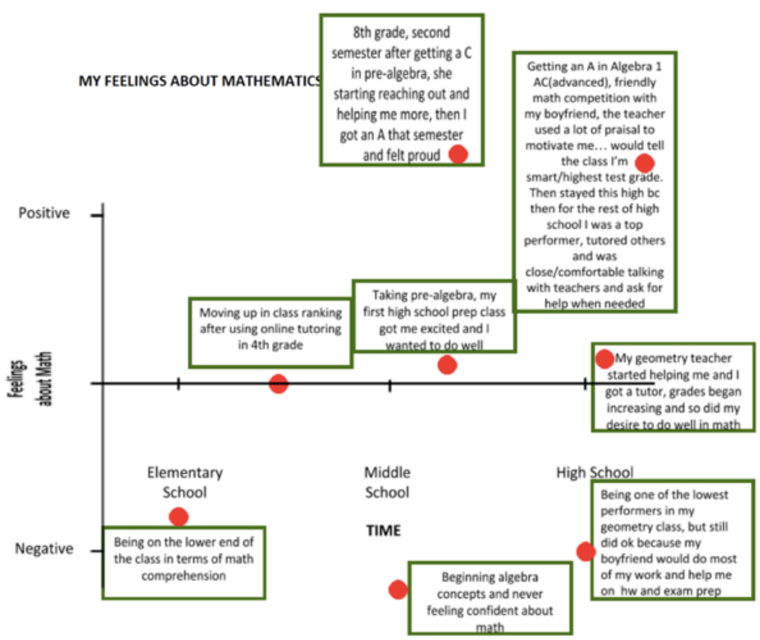
That changed in eleventh grade when Participant 11 had a geometry teacher who would challenge her and let her work on learning mathematics outside of the course curriculum. Then, in twelfth grade, her attitude declined when she had who she called "just about the worst teacher ever known to man." She said the teacher did not teach well, would either yell at students or applaud them, and was unstructured and unprofessional. She said because the teacher was "a joke," calculus became a joke to her as well. She said enjoyed her college experiences – a survey of calculus course and her elementary mathematics content courses – enough to bring her back to positive feelings about mathematics, noting that her survey of calculus instructor made the course "fun and didn't just sit up there and lecture the whole time" while she felt the mathematics of the elementary content courses was more relatable to her future career.

Neither Participants 4 and 9 noted specific turning points in their interviews and hence were classified into the *Minor Setback* category. Both recalled many positive experiences with mathematics both before and after their one recalled negative experience with mathematics, and those experiences did not seem to affect them past the time frame in which they occurred. Participant 11's experience, however, did not fit comfortably in one category and much better in two. I classified her as *Snowballing* for her time from elementary school through her sophomore year of high school before she began her *Roller Coaster* experiences afterward. In her autobiography, she even called her experiences in high school a roller coaster. In her interview, she noted three major turning points: a) her first positive experience in second grade when she felt challenged, b) her first positive experience in high school when she felt her junior-year geometry teacher cared about her and challenged her, and c) her negative experiences with her "joke" calculus teacher and class.

Strongly Like (*n*=3). Like the participants in the neutral group, those in the "Strongly Like" category produced very different attitude graphs. Participant 2's graph (seen in Figure 7.5) oscillated between negative and positive, Participant 3's began very negative and climbed late in her experiences, and Participant 5's was the only participant of my 14 interviewees whose graph

Figure 7.5

Attitude Graph for Participant 2.



consistently depicted a positive attitude toward mathematics. All three strong likers also cited very different influences on their attitudes toward mathematics, as depicted by their annotations on their graphs as well as what they wrote about in their autobiographies and spoke about in their interviews.

Participant 2 was highly affected by performance outcomes. Her lowest points in her graph were tied to being in the lower end of her class in performance and experiences that brought about increases were tied to getting As, being praised for her test scores, and outperforming her peers. In both her autobiography and interview, she emphasized doing whatever she could for higher grades (e.g., getting a tutor, working with her "smart boyfriend") and being disappointed if she was not outperforming her peers. Also, she noted (and it can be seen on her graph) that each starting point of elementary, middle, and high school was a low point as she adjusted and had to figure out how to perform well again in a new school setting with new teachers and new content. Her attitude rose consistently within each school setting and finally remained at its highest point from her sophomore year onward as she performed well and became comfortable talking to her teachers and asking for help.

Participant 3 described herself as mathematics-anxious throughout her K-12 experiences. While she had one good experience during her freshman year of high school with a particularly patient and understanding Algebra I teacher, she did not really begin to enjoy mathematics until she got to college. Her first good experience in college was going back to her high school for some volunteering. She was asked to help out in a mathematics classroom and said that she found many students were going through similar experiences to hers; they were mathematics-anxious and struggling to understand what they were learning. Meanwhile, she was taking a college algebra course and was doing pretty well in it. She encouraged the students that they could do it since she had struggled for so long and was able to do well in college algebra. Her attitude then reached her highest point in her most recent elementary mathematics content courses, as she finally understood the elementary mathematics content that she had struggled with for so long.

Participant 5 liked the problem-solving aspect of mathematics. She felt finding the correct answers was rewarding. Her attitude dipped a little bit when she started having to take timed tests, which gave her fear that she would not perform as well as her peers. After she moved past timed tests, she said her enjoyment of mathematics was restored until her district switched to the "Common Core math standards" in middle school. She felt like she no longer knew if she was doing mathematics correctly because the teachers "were told to answer all of our questions with another question." She also disliked the curriculum's attempt at relating mathematics to the real world, which she thought was superficial. Her like was restored once more when she switched to a private high school that did not "use the Common Core." She found comfort in returning to a more lecture-based, direct instruction style of teaching that was more like her experiences in elementary school. She also had a great relationship with her teachers, which helped maintain that positive attitude toward mathematics.

All three participants in this group noted turning points in their attitudes toward mathematics. Participant 2 spoke to multiple turning points, saying "my main turning points is when I would fail and do really badly in a class or when I would do really good that I felt like I had an expectation to continue doing good." I classified her as *Roller Coaster*, because her graph presented many ups and downs, and she described multiple turning points. Participant 5 was classified as *Minor Setback* since, though she had a few negative experiences, they did not derail her overall positive attitude toward mathematics. She said that she saw leaving the Common

Core curriculum as a positive turning point, and you can see that it restored her highly-positive feelings about mathematics after a slight down-turn in middle school.

Participant 3, though having a few positively plotted points beforehand, called her experiences in her college elementary mathematics content courses her turning point. She said that those courses finally helped her understand the foundational mathematical shortcomings of her K-12 experiences. She said "I have learned and mastered more mathematics in one semester of college than I learned in the nineteen years of my life prior" and that while she did better in college algebra, it still provoked many of the same feelings as her K-12 experience. Hence, I classified her as having a *Positive Turning Point*. She had consistently negative feelings about mathematics (despite having some good experiences in it) until her most recent college experiences. She opened her autobiography with a play on a common mathematics joke by saying "six and I were both afraid of 7. For me it wasn't just because 7 ate 9, rather I couldn't memorize and perform with speed my times tables past 6." After describing her college experiences, she appropriately wrote "Six is probably still terrified of seven, but seven doesn't make me cry anymore." I feel these two small quotes depict her pre- and post-turning point attitude well and do a good job illustrating the positive turning point classification.

Table 7.11 gives a summary of which participants fell into which turning point story category, a brief description of the turning points each described, and at which level of schooling (Elementary School, Middle School, High School, University) the turning points occurred.

Table 7.11

Turning Point Story Categorization along with Turning Point Factors and Timing

Turning Point Classification	Participant ID	Attitude Rating	Turning Point(s)	School Level(s)
Roller Coaster	6	2	Neg. – Teacher yelled at students for wrong answers	Elementary/Middle
			Pos. – Relating to Elementary Mathematics Content	University
	10	2	Pos./Neg. – Dependent on Teacher	Throughout
	13	3	Pos./Neg. – Dependent on Course/Topic	Throughout
			Pos. – Helpful Teacher	High
	11	4	Pos. – Teacher challenged her	High
			Neg.– “Joke” calculus teacher	High
	2	5	Pos./Neg. – Performance Outcomes	Throughout
Snowballing	1	1	Grades and Teachers	Throughout
	14	3	Summer Mathematics Program, Ability Grouping, Lack of Understanding	Elementary, Middle, High (respectively)
	11	4	Not feeling challenged	Elementary/Middle
Negative Turning Point	7	2	Ability Grouping	Elementary
	8	2	Boys moved up to algebra, not her	Middle
	12	3	Teacher refusing to help	High
Minor Setback	4	4	None Expressed	N/A
	9	4		
	5	5	Pos. – Familiar Instruction Type	High
Positive Turning Point	3	5	Understanding Content in Elementary Mathematics Content Course	University

The most common classification for turning point stories was *Roller Coaster*, with five participants citing multiple turning points at various points in their histories with mathematics. No participant had an always-positive *Smooth Track* or conversely always-negative *Consistently Frustrated* classification. Aligning with the outcomes depicted in Tables 7.6 and 7.8, participants most-often cited various teacher factors – both positive and negative – and performance outcomes – mostly negative and included both grades and being left behind in ability grouping – as reasons behind specific turning points. Negative turning points were cited as occurring relatively evenly across elementary, middle, and high school, but positive turning points were most-commonly cited at the high-school and university levels.

Chapter Summary

In this chapter, I first presented the results from my data related to the research question, *What experiences do preservice elementary teachers attribute to having shaped their attitudes and beliefs about mathematics?*, with a focus on attitudes toward mathematics. Through an iterative process, I developed categories of reasons participants gave for their various attitudes toward mathematics. When respondents were asked for a short-answer response describing why they felt the way they did about mathematics, they most commonly responded within the category *Beliefs about Mathematics*. The next most-common responses fell within the *Innate Ability; Connected to Understanding;* and *Course or Topic Dependent* categories. When I analyzed their short-answers for tone, I found that the tone of dislikers' responses within categories was almost completely negative and the tone in the likers' responses was mostly positive. While neutral participants' responses generally carried a neutral tone, eleven of the 42 neutral responses were exclusively negative in tone while no responses were exclusively positive.

I also read and categorized reasons for attitudes expressed by the whole group within a sampling of their Mathematics Autobiographies. Unlike in the short-answer responses, participants' statements fell most-commonly into the categories *Teacher Factors* and *Performance Outcomes*. In terms of tone, a different picture than the short-answer responses emerged as well. Those who dislike mathematics and those who liked it did write more negative and positive statements, respectively, but the likers still produced many negative statements, especially when discussing certain courses or topics and teachers. Those who indicated feeling neutral about mathematics had many more negative statements than positive statements within the categories. In fact, all but three of the sixteen categories for the "neutrals" had more negatively- than positively-toned statements.

A similar analysis of autobiographies was carried out for my interview participants, but only for the statements they highlighted themselves as important during the interview process. Like with the whole-group, interviewees mentioned *Teacher Factors* and *Performance Outcomes* most commonly as impactful on their attitudes toward mathematics. Interviewees tended to highlight more negative statements than positive, and those in the "like" and "strongly like" attitude groups even had more negatively-toned statements (in total between them) than positive.

Lastly, I gave the results from analyzing the interview participants' attitude graphs, including those plotted events they said in their interviews were turning points in their attitudes. Aligning with the results from the whole-group and interview autobiography analyses, interviewees most-often annotated their graphs with experiences related to their experiences with teachers, including their instruction style, willingness to help, ability to challenge participants, and their personality or personal interactions with students. Continuing this alignment of results, interviewees cited teacher factors and performance outcomes most-often at positive or negative turning points in their attitude toward mathematics. Negative turning points were cited as happening relatively evenly across schooling levels, whereas positive turning points were most common at the high-school and university levels. The most common classification of their turning point stories was *Roller Coaster*, with five interview participants depicting up-and-down relationships with mathematics with multiple turning points in their attitudes.

The results from this chapter taken on the whole continue the story started in Chapter 5 that attitudes toward mathematics are not fixed, and we saw here that they are relatively easily changed by their experiences – especially with their – and by the alignment (or misalignment) of their experiences with their beliefs about mathematics or judgements of their innate ability. In the deeper analysis of the interviewee data, we see, however, that some experiences can affect some people's attitudes toward mathematics more deeply than others. For instance, Participant 8's experience of being left behind in mathematics while her similarly-achieving male peers advanced to a higher level left a residual effect that lasted the rest of her life whereas other events, like believing a negative stigma about mathematics perpetuated by her peers (Participant 4) or feeling forced to take calculus (Participant 9), had only temporary negative impacts on participants' attitudes.

Chapter 8: Discussion

In this chapter, I consider the results of this study in relation to prior research on preservice elementary teachers' attitudes toward, and beliefs about, mathematics. First, I will summarize the findings for each research question in the same order as the prior chapters – beginning with attitudes before discussing beliefs and finally the relationship between them. Then, I will discuss the implications of these findings before recognizing the limitations and proposing ideas for future research on people's attitudes and beliefs about mathematics. I end with some concluding remarks as I reflect on the study. Recall that my research questions were:

1. *What is the overall landscape of attitudes toward mathematics amongst preservice elementary teachers?*
2. *What beliefs do preservice elementary teachers with positive and negative attitudes hold about the nature of mathematics?*
3. *What types of experiences do preservice elementary teachers attribute to having shaped their attitudes and beliefs about mathematics?*
4. *What types of experiences tend to be turning points in the mathematics attitudes and beliefs of preservice elementary teachers?*

Findings Connected to Attitudes of Preservice Teachers

My first research question concentrated on gaining an understanding of the range of, changes in, and complexity of the attitudes my population of PSTs held toward mathematics. Three important findings emerged: (a) This group of PSTs' self-reported attitudes toward mathematics were generally positive, (b) not all participants' Likert-scale self-assessments of their attitude aligned with their other data sources, and as a consequence, (c) numerical responses to the initial survey obscured substantial complexity as to how participants interpreted their attitude rating choices. Results from both the whole-group and interview participants data analyses support these observations. Each of these observations will be discussed in turn.

Results from the whole-group responses to the first survey question, where participants were asked to rate their feelings toward mathematics on a scale of 1-5, indicated that more PSTs in this population liked mathematics than disliked mathematics. Nearly half of the participants reported liking or strongly-liking mathematics, while few (relative to the whole) reported disliking or strongly disliking mathematics. This result is strikingly different from prior research that has reported that PSTs generally dislike mathematics and tend to be mathematics-anxious (e.g., Bursal & Paznokas, 2006; Kelly & Tomhave, 1985). Though there were disparities between some participants' attitude ratings and reasoning behind them (where some "neutral" participants tended to focus on the negative aspects of mathematics), there were still many more "likers" than "dislikers" in this population of PSTs. This was an encouraging result in that it provides some evidence that "not all hope is lost" for the attitudes of incoming PSTs toward mathematics. These positive results, in turn, meant I could perhaps gather more information about the experiences that helped develop *positive* attitudes toward mathematics than prior research. The findings on such experiences will be discussed later.

My second finding – that not all participants' Likert-scale self-assessments of their attitude were in alignment with other data sources – was evidenced both by the noted disparities between the whole group's ratings and their explanations for their ratings and by the interview participants' attitude graphs. Though relatively few PSTs' written responses on the whole did not align with their numerical attitude ratings, most of the inconsistent responders responded with neutral (3) on the five-point attitude scale but sounded more like they disliked mathematics than were actually neutral. Perhaps more surprising were the results of the interviewees, where three groupings of similarly-shaped attitude graphs depicting their attitudes over time came from different attitude ratings between PSTs in each group. These findings give evidence that participants frequently interpreted the meanings behind their numerical ratings in different ways with respect to their experiences.

The evidence for observation (b) above also leads me to my third observation: That attitudes towards mathematics reported on a Likert-scale survey are more complex than their face-level value. The identified disparities summarized above, coupled with the interview responses about participants' choices of rating levels, implied that people can interpret Likert-type survey rating options very differently from each other. Some participants chose their rating level as an average of their experiences over time, whereas others chose a rating based on their most recent feelings toward mathematics. Still others chose a rating as an average of their experiences across different topics of mathematics (liking some topics but not others). Hence, this was a second set of findings showing that participants viewed the meanings behind their numerical attitude judgments differently from one another. Groups of participants reported similar experiences and subsequent attitudes over time, yet they made sense of them in their numerical ratings differently.

Findings Connected to Beliefs

In this section, I discuss the findings as they relate to my second research question focusing on the beliefs of PSTs with varying attitudes toward mathematics. I also include in this section findings that relate to the beliefs portion of my third research question – experiences influencing beliefs. Despite some limitations in the way I sought to collect beliefs data (see limitations section below), four important findings about participants' beliefs about mathematics emerged from the analysis: (a) some PSTs bring beliefs about mathematics into their teacher preparation programs that are directly opposite to some of their peers, (b) Teachers and others have an (often negative) impact on PSTs' beliefs about mathematics (c) Those beliefs are more fluid than fixed, and (d) beliefs about mathematics seem to shape PSTs' attitudes, but in different ways for different candidates. Data from three survey questions, the autobiographies, and interviews constitute evidence for these claims.

My first claim stems from the results of the cumulative counts within different categories of beliefs that emerged in my analysis. Relatively frequently, PSTs, especially those who disliked mathematics, reported beliefs that mathematics problems allowed for only one solution path, while others, especially those who liked mathematics, saw mathematics as allowing for multiple ways to solve problems (even if they reported liking the presumption of one right answer). While many more PSTs saw mathematics as applicable to their lives and to making sense of the world, some indicated that mathematics has no applicability. More PSTs expressed the belief that mathematics is an ability that some have and others do not than PSTs expressing the converse belief that mathematics is for everyone, or that with hard work anyone can do mathematics. Beliefs exhibited by participants that mathematics is about *a process* could be seen as oppositional to mathematics being about *the result* (e.g., finding an answer). While only a few participants explicitly called mathematics a process, many participants wrote that mathematics is about "problem solving," which could be seen also as a process. More in-depth research would have been needed to see how many participants perceived "problem solving" as a process and "finding a solution" as a result. But the assumption of and focus on single "answers" can certainly lead to frustration or negative attitudes when solutions are difficult to come by or reward and positive attitudes when they are more-often found. Regardless, it is an important result to know not only that groups of PSTs hold a variety of beliefs about mathematics, but some of those beliefs are oppositional in nature. This is an important realization given that teachers' beliefs about mathematics can have more of an influence on their instruction of mathematics than the methods for, and beliefs about, teaching and learning they learn about during teacher preparation (Phillipp, 2007; Putnam et al., 1992; Raymond, 1997).

Analysis of the autobiography and interview data supported claim (b) above, that teachers (especially), peers, parents, and members of the community can (often negatively) affect PSTs' beliefs about mathematics. Participants frequently reported that their K-12 teachers influenced their (pre-university) belief that there was only one way to solve mathematics problems by requiring them to find solutions in particular (the teachers') ways. Eight interview participants gave accounts of teachers pressing them to use certain solution paths, marking correct answers incorrect if they chose their own path, or requiring answers to be written in certain formats. Participant 4 received the negative message from her peers that mathematics is awful and hard (calling it "the stigma"). Participant 8 overtly expressed receiving the message that she, as a woman, did not belong in mathematics—a finding that is sadly not an isolated on in mathematics education (e.g, Tomasetto, Alparone & Cadinu, 2011) and is vitally important with women representing over 90% of elementary teachers in US schools (Stoehr, 2017).

But not all beliefs that participants reported that were influenced by others had a negative cast. Five of the eight participants who held the belief during K-12 that there was one way to solve mathematics problems reported that their beliefs changed through their college experiences, particularly in their elementary mathematics content courses. They indicated that their instructors played a major role in changing that belief through their emphasis on showing and asking for multiple solution paths to solutions. Participant 4 was influenced by her family, especially her brothers, who pulled her out of believing “the stigma” that mathematics is something terrible.

This evidence, in part, informed my third claim that beliefs are often not fixed but dynamic, and that they can change quickly. Scholars (e.g., McLeod, 1992; Philipp, 2007) have characterized beliefs as relatively stable constructs that are difficult to change. My participants, however, were sometimes quick to change their beliefs when they experienced mathematical work in meaningful and positive ways. I already mentioned participants previously who experienced changes in their years-long held beliefs over the course of just one semester in their elementary mathematics content courses and another whose belief changed in a year as influenced by family members and other concurrent positive experiences with mathematics. Participant 8’s beliefs began to change negatively when she was not moved to algebra while her similarly-achieving male counterparts were, and unfortunately those beliefs were reinforced over time.

This change in Participant 8’s beliefs also changed her attitude toward mathematics. She said that once she realized that she did not belong in mathematics, she began despising it. Hence, my fourth claim is that beliefs have an impact on attitudes, and the nature of the influence is different for different people. A number of dislikers talked about their belief that mathematics learning depended on innate ability that they lacked as a reason for their negative attitude. Dislikers likewise seemed to feel that there are “mathematics people” and “non-mathematics people.” The twin beliefs that (1) mathematics is for some and not others and (2) some are incapable of understanding seem to underlie their dislike.

Lastly, similar beliefs about mathematics seemed to affect PSTs' attitudes in different ways. Dislikers offered their frustration in not being able to find "the one solution" (a belief that there is one solution) whereas many likers expressed "liking" or even "loving" that there is one solution. Dislikers and likers both expressed at times that they found mathematics to be hard or challenging, but dislikers indicated the challenge as the basis of their negative attitudes while likers expressed enjoying the challenge. Dislikers and likers both expressed that mathematics has rules, formulas, and a certain structure to it. Dislikers tended to focus on this as a limiting factor, whereas likers tended to connect it to an opportunity to be creative within the structure.

Findings Connected to Experiences Informing Attitudes

I found that certain kinds of experiences seemed to be interpreted similarly (either carrying a positive or negative tone) by all PSTs regardless of their numerical attitude ratings, where other experiences were interpreted by some as positive and by others as negative. Secondly, I found that when asked explicitly for reasons for their attitudes, participants tended to cite their beliefs about mathematics, innate abilities, and levels of understanding, but when asked to give historical accounts of their relationships with mathematics they most often mentioned teachers and performance outcomes. Thirdly, I found that while mathematics dislikers expectedly recounted more negative experiences with mathematics than positive, mathematics likers and neutral participants tended to recount negative experiences nearly as often as positive experiences.

I noticed that across all data sources analyzed for experiences (survey question, autobiographies, and interviews) beliefs about mathematics were one of the most polarizing category of reasons given by participants for their attitudes. Participants who reported disliking mathematics reported quite negative beliefs about mathematics while participants who liked mathematics were overwhelmingly positive in their belief statements about mathematics. Very few dislikers mentioned beliefs that suggested a positive orientation to mathematics (e.g., as an exception, Participant 8 liked that there were multiple solution paths to an answer) and likewise very few likers mentioned beliefs that suggested a negative orientation (e.g., Participant 11 disliked that mathematics "shows people like how smart you are in a way"). Statements about participants' sense of their innate ability aligned similarly. Dislikers across all three data sources tended to mention not feeling they were capable or were "not a mathematics person," whereas likers tended to point to mathematics coming easily to them or having confidence in their abilities. What was, however, more unexpected was that "neutral" participants aligned more with dislikers than likers, tending to provide negative beliefs and portraying their innate abilities in negative ways.

Two other categories of experiences, peer comparison (which only showed up in participants' autobiographies) and test taking, were viewed negatively by participants across the numerical attitude scale. Participants often reflected negatively on the messages they received from peers (like the negative "stigma" Participant 4 mentioned), the messages they received by comparing themselves to their peers (like seeing their friends move to advanced mathematics while they stayed behind), or by noticing they were finishing assessments slower than their peers. For test-taking, participants across all levels commonly stated they simply did not like or underperformed on mathematics tests.

When participants gave their historical accounts with mathematics, positive or negative experiences with performance outcomes (e.g., grades, class placement), understanding, and teachers were most directly influential on participants' respective positive or negative attitudes toward mathematics. Many likers pointed to positive performance outcomes in their autobiographies, neutral participants were relatively evenly split in reporting performance across data sources, and dislikers in the whole-group sample did not discuss performance very much. But the interviewee dislikers reported many negative performance outcomes. Understanding or lack thereof was also important to participants' feelings about mathematics. When PSTs wrote about understanding, it was almost always attached to a positive or negative tone, such as "I struggle with comprehending mathematics therefore it doesn't make it an enjoyable subject for me" or "when I understand the concepts, I get excited."

Teachers were discussed positively and negatively across data sources in nearly equal measure. Likers reported only slightly more positive experiences with teachers than negative, and dislikers mentioned only slightly more negative experiences with teachers. In short, participants who mentioned their teachers tended to mention both good and bad experiences during their mathematical journeys. These findings further confirm the powerful role that teachers play in how people experience and subsequently are affected by mathematics (Young-Loveridge, Bicknell, & Mills, 2012). One encouraging finding, however, was that a number of my interviewees indicated in their attitude graphs and stories that they were able to find ways to recover from "bad" teachers.

With regard to my second finding about the role of mathematical experiences in the formation of attitudes, it was interesting that when asked for *the* reason they chose their attitude rating, participants tended to cite their beliefs about mathematics (e.g., it is too hard, it is fun, it is like a puzzle) or self-assessed innate abilities. Yet, when they wrote about their personal histories with mathematics in their autobiographies, they focused mostly on their experiences with aspects of school mathematics (their teachers, grades, courses they took). I acknowledge that their beliefs about mathematics were certainly informed by their experiences in school. Beliefs about mathematics as being too hard, generating too much homework, or being fun or boring would have likely formed from their experiences in schools and likely their experiences with how their teachers taught (fun, boring, challenging) or by the grades they received (hard, easy). Nevertheless, participants expressed their beliefs about the nature of mathematics as reasons for their attitude for more frequently in the question asking specifically for *the* reason for their attitude (where they perhaps were thinking about mathematics generally), whereas their focus changed to their K-12 experiences in shaping their attitudes with mathematics when asked to write about their relationship with mathematics over time, prompting to think more about school experiences.

My third finding was that where dislikers reported, as expected, more negative experiences than positive, neutral and likers did not do so as consistently. Neutral participants cited more negative experiences across all three data sources than positive, and in the sample of autobiographies they wrote about more negative experiences within nearly every experience category. Even though likers generally recounted more positive experiences than negative, they still reported a surprising number of negative experiences, especially bad experiences with teachers, certain courses or topics, and negative positioning by peers. Most all the interview participants drew graphs and added annotations that indicated negative experiences, and there were no “smooth track” graphs. These findings imply that many PSTs come to their teacher preparation programs with some negative experiences with mathematics, and they can either find them defeating (and dislike mathematics), persevere through them (and like or maintain liking mathematics), or feel an indifference toward mathematics as a result. These findings further complicate the “meaning” of participants’ Likert-scale attitude ratings while also pointing to a perhaps fundamental issue of recall – namely that negative experiences may be remembered more frequently than positive (Ochsner, 2000).

Findings Connected to Turning Points

First, the most common turning point profile for my participants was that of *Roller Coaster*. *Snowballing* was another common story/profile, while no one reported having a *Smooth Track* or *Consistently Frustrated* story. The up-and-down nature of many of the attitude graphs, each annotated with a reason for the change, along with these turning point stories illustrate not only the fluidity of attitudes, but also give evidence to how quickly attitudes toward mathematics can be influenced by experiences, especially those of teachers and their courses. Also, the fact that interviewees indicated having their attitudes change, and sometimes drastically (see Participant 3) after their K-12 experiences signals that it does not seem to ever be "too late" for attitudes to change.

Teachers played a pivotal role in participants' turning points. Interviewees frequently reported experiences with particular teachers as marking turning points in their attitudes toward mathematics. This pattern aligns well with the autobiography data where many participants wrote about experiences with teachers in both positive and negative ways. Teachers also played a covert role in the next-most common turning point experience category – performance outcomes. Participant 7's fifth grade teacher made the decision to leave her out of the "advanced class," which left her feeling incapable in mathematics. Participant 10 likewise reported a negative experience with ability grouping: Her teacher would let students sit in the hall if they passed a pretest, and she was not included. Participant 8 relayed a major turning point when she was left in pre-algebra while her similarly high-performing boy peers were moved to algebra. Her teacher's failure to vouch for her assisted in her reception of the message that mathematics was for boys and not for girls.

A related finding was that negative turning points were experienced relatively evenly across elementary, middle, and high school, where positive turning points were most commonly noted in high school and university years. Both university turning points happened in the PSTs' recent elementary mathematics content course, and nearly all high school turning points (both positive and negative) were connected to experiences with teachers.

Implications

With this summary of the results in mind, I discuss the implications of this study, first for methods of research that explore PSTs' attitudes toward and beliefs about mathematics before turning to pedagogical and theoretical implications.

Methodological Implications. I begin with the implications my findings have for research methods, beginning with the use of surveys in attitudes and beliefs research before discussing the potential of some of the methods utilized in this study.

Survey use in researching attitudes and beliefs. The findings related to my first research question point to the complexity obscured when participants selected a Likert-scale rating for their attitude. Likert-scale and force-choice survey use is the prominent method used in researching attitudes and similar concepts like mathematics-anxiety (e.g., Gresham, 2007; Harper & Daane, 1998; Kelly & Tomhave, 1985). Yet, the variety of reasons participants reported for their choices and evidence of my interview participants' changing attitudes over time raise questions about the validity of such measurements. One major flaw is that a single number collapses together cases where the number is a momentary choice based on "feeling good about mathematics" after just having left a good mathematics class with those where a participant makes a choice reflecting an average of their experiences. Often my data indicated the latter – that the participants in studies have an "attitude," when in reality, attitudes may fluctuate frequently based on circumstances. My findings may also indicate a bias for participants to report their attitude toward mathematics as higher (in rating) than the details of the experience would suggest. The basis of this bias is uncertain, though the fact that their mathematics instructor was reading the survey results may have contributed.

Similarly, my findings indicate a similar fluctuation in beliefs over time. The beliefs captured in a force-choice survey may only reflect the momentary beliefs (or influence the data on their beliefs by giving them limited choices), and hence may become outdated after their next significant mathematics experience. Surveys designed to capture attitudes and beliefs would benefit from required open-ended follow-up questions asking for the reasoning behind the choice, in terms of experiences informing the choices. They may also explore whether participants' choices represent their attitudes or beliefs at the moment, those established over a long period of time, or some sort of average of their attitudes over time or uncertainty in their choices of beliefs. Attitudes and beliefs in my study proved to be dynamic in nature, changing over time, and hence surveys would benefit from taking that into account in their design.

Attitude graphs. The decision to ask my participants to draw and annotate an attitude graph to illustrate their feelings toward mathematics over time proved to be very helpful in both seeing a picture of the changes in their attitudes that were written about in their autobiographies, but also supporting discussion of points and garnering further information that they had not mentioned previously. In short, graphing was a useful tool in extracting more information as well as illustrating the paths that interview participants took in their relationships with mathematics during K-12 (and beyond, for some). It perhaps was the most direct demonstration of the problems with using numerical ratings as the sole bit of information about people's attitudes, which are often changing entities based on experiences.

Surfacing Beliefs. This study utilized a new way to explore PSTs' beliefs; prior studies have tended to have PSTs write about their beliefs using metaphors (Cassel & Vincent, 2011; Latterell & Wilson, 2016) or used semi-structured interviews (e.g., Katmer-Bayrakli & Erisen, 2019) to draw out participants' beliefs. All of my methods utilized participants' expression of what they believed mathematics to be without being asked to express their beliefs in certain ways (e.g., through the use of metaphors) or with time constraints on their thinking or the presence of other people (as in interviews). In some cases, when participants used metaphors to express their beliefs (e.g., "I like to think of mathematics as solving a puzzle," "I believe mathematics is a universal language"), but without suggesting certain responses and giving them time to express their thinking, I was able to establish many categories of beliefs from the use of a few simple open-ended survey questions.

Also, this research showed not only what beliefs PSTs hold, but how they affected their attitudes and in what ways. The methods used in this study showed that the same belief can support both liking and disliking mathematics (e.g., believing there is only one possible solution). It also gave evidence that some beliefs are likely to only have an effect on attitude in one direction (e.g., mathematics is boring – negative; mathematics is fun – positive). While prior research has importantly found *what* beliefs PSTs might hold through the use of interviews and metaphors, this research has opened new doors into *how* those beliefs affect individuals' attitudes toward mathematics and in what ways.

Lastly, this research showed the benefits of utilizing different methods for exploring beliefs within a population. When asked about their beliefs about mathematics through open-ended survey questions, I received different, and some completely unique, responses depending on how I asked the question (e.g., asking what math is all about versus asking how it differs from other school subjects). Each layer of analysis across the various data sources (survey questions, autobiographies, and interviews) utilized new and unique beliefs statements and categories that were not found in the other data sources and expanded many of the categories that were previously found.

Pedagogical Implications. The findings also have implications for instruction, in both K-12 and collegiate classrooms.

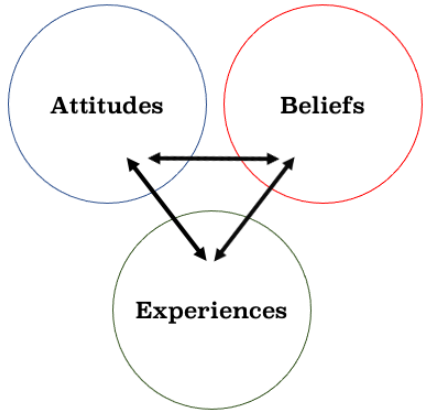
Teachers' power. This study showed how students experienced their K-12 teachers' personal, and often inappropriate, teaching practices and associated beliefs about doing mathematics (e.g., solving problems a certain way, writing answers in a certain format). Those practices and beliefs were often felt at a deep level and in negative ways. Some students have subsequent experiences that help "right the ship" in their relationship with mathematics, but many had to wait until high school or college for those. Teachers have power that can be used either badly (in promoting unhealthy beliefs and attitudes about mathematics) or well ("opening up" a subject that had been more closed). They may be unaware of or underestimate the negative effects they may have on attitudes and beliefs about mathematics. It is important for PSTs to recognize their histories with mathematics and have an opportunity to share them during their course of teacher preparation as a means for their own "recovery" before entering their classrooms, as well as reflect on them as they look forward to their own classroom practice in their future classrooms.

Elementary mathematics content courses. Fourteen whole-group participants pointed specifically to their university content courses as the setting where they recovered from some of the problems with mathematics they encountered in their K-12 schooling, though a few had more negative experiences and found their elementary content course perpetuated their previous experiences and feelings. It is vital that instructors of such courses know that their students come in with a variety of attitudes and beliefs. It is also important to recognize that, for some, those attitudes had been reinforced year after year, and yet, the experiences they had in the university content course could change their attitudes substantially. Likewise, instructors should know that the beliefs they support in their classes, whether healthy or (hopefully unknowingly) unhealthy will likely be met with opposition by some incoming students. Yet, this study shows there is hope that beliefs can be changed for the better over a short period of time. Future research should focus on what assignments or activities bring about such recovery and change for the better.

Theoretical Implications. This study showed that beliefs about mathematics can be, and may be generally, less stable than some researchers (e.g., McLeod, 1992) have previously thought. It also gave evidence to how experiences, attitudes, and beliefs interact in important ways. For many of my participants, certain experiences seemed to affect both attitudes and beliefs concurrently. For example, the feeling of being left behind in pre-algebra while her equally-successful male counterparts moved up to algebra gave Participant 8 a belief that mathematics was not for girls and an immediate dislike for mathematics as well. Others expressed that recurrent events of poor grades while seeing their peers succeed rather easily informed negative attitudes while also leaving them to believe that they were “non-mathematics people.” The results of this study infer the possibility of a dynamic, multidirectional relationship between attitudes, beliefs, and experiences. Figure 8.1 illustrates this relationship between experiences, attitudes, and beliefs hypothesized from this study that warrants more attention in future research along with more research on how quickly and often beliefs can change over time.

Figure 8.1

A model for the relationship between attitudes, beliefs, and experiences.



This diagram contains double-ended arrows among attitudes, beliefs, and experiences. The design of the study was meant to emphasize direction of influence from beliefs to attitudes, as McLeod's (1992) framework hypothesized beliefs as foundational in the formation of attitudes. I further hypothesized experiences as a mediating factor for both beliefs and attitudes. Hence, the findings described above show the substantial effect of experiences on attitudes, of experiences on beliefs, and of attitudes and beliefs effects on each other (the effect of attitudes on beliefs was a supplemental finding of the study). What was less overtly described by the results were the effects that attitudes and beliefs can each have on experiences. A few examples can be given to justify them here, but direction of influence from attitudes to experiences and from beliefs to experiences could certainly warrant more attention in future research. One example from the study showing relationships of mutual influence between the three constructs is Participant 4's story of her believing "the stigma" that mathematics was hard and awful while in middle school. Her experiences (namely, with her peers) initially helped develop her belief in the stigma, and in turn, she mentioned how the stigma affected both her attitude in mathematics (turned it negative) while also affecting her experiences by perpetuating the belief herself – saying that she would "say mathematics sucked" even though she received good grades in it. In sum, her experiences influenced her belief that mathematics was awful, which she said caused her to dislike it, which, coupled together, caused her to experience it and discuss it in negative ways, despite her success.

Limitations

The data gathered in this study was retrospective in nature. Ericsson and Simon (1980) identified problematic issues of using verbal reports of memories as data. The authors stated, "when information is not in memory, it cannot be reported verbally" (p.243). Though I limited my study to young adults who had recently completed their K-12 schooling, there were instances where they were unable to answer certain questions because they had difficulty remembering certain parts of their K-12 experiences. Also, researchers have found that negative memories tend to be more easily recalled in general than positive (e.g., Ochsner, 2000). This could be a factor in why my mathematics likers tended to recall more negative memories than I had expected. Lastly, by definition, the past memories of my participants were being reconstructed and reshaped by their present. Though their memories are no less meaningful to them, my participants may not have had the experiences they recollected exactly as they recalled them.

Another limitation was the narrow range of diversity of participants in my sample. Participants where overwhelmingly white and female in the whole group. All those who volunteered for interviews were white females, mostly from suburban backgrounds. While this population may be representative for the institution at which they attended and other institutions with similar demographics in their teacher education programs, I recognize that certain findings did not emerge that may better represent the full, diverse population of who could become an elementary teacher. Hence, my findings may possess some generality, but they cannot be taken to reflect the experience and thinking of all those who wish to become teachers.

Despite the value in using the Mathematics Autobiographies as data, especially for participants' experiences as they related to their attitudes about mathematics, there was one design flaw that limited my hope in finding their turning points. While I asked them to include turning points, I was not explicit enough about either the meaning of turning points nor about making it a requirement of their writing to include them. I hoped for more whole-group participant data on turning points, but since so few used the words "turning point" or similar words in their writing, I elected not to do so. If I had, I would have been left to surmise their turning points based on stronger tone. Hence, I used only my interview participants' data only for my fourth research question.

A final limitation was my limited success in uncovering beliefs beyond the responses to Survey Questions 6 and 7. While those two questions proved fruitful, the rest of the questions beyond those that were designed at understanding my participants' beliefs proved mostly unproductive. In addition, belief statements did not emerge from the interviews as much as I had expected. I found it easier to recognize attitudes (due to keywords, such as like, dislike, love, hate) than recognize beliefs, and follow up appropriately, during the interviews. My designed beliefs interview questions were more confusing for interviewees than I had intended, and I struggled to adjust them before I was finished with interviewing all fourteen interview participants. In retrospect, perhaps explaining how I was thinking about beliefs more clearly before asking them questions about their beliefs, or having my ears better tuned toward beliefs responses to ask appropriate follow-up questions would have improved the results of the study.

Recommendations for Future Research

Based on the results reported in this study along with some gaps that remain due to some of the design flaws or limitations of this study, I can make some recommendations for future research on attitudes toward, and beliefs about mathematics.

Teacher Preparation. The results of this study indicate that some participants found their university elementary mathematics content course improved their attitudes toward mathematics or alter their beliefs about mathematics. Some listed factors related to their own understanding of mathematics as a reason for attitude improvement, others pointed to instructional factors, and a few left the reasoning behind their positive changes in attitude unknown. With respect beliefs, some encountered instructors of the same course who emphasized multiple solution paths to solve problems. I am still left wondering, however, what factors were left unsaid? I also wonder how the data might shift during the course of their teacher preparation programs. How do their incoming attitudes and beliefs change from their first year in the university setting until the time they leave the program?

Future research should look specifically into how elementary mathematics content courses, and perhaps methods courses, could be used as recovery or therapy for preservice elementary teachers who bring painful experiences and negative attitudes toward mathematics to their professional preparation. Narratives not unlike the Mathematics Autobiography have already shown to be one avenue for rehabilitating mathematics identity (e.g., Lutovac & Kaasila, 2011), but more research is warranted on its use as a recovery method for attitudes and beliefs about mathematics. Researchers should consider longitudinal approaches that assess attitudes and beliefs early in the program, after each elementary mathematics content or methods course, and after their student teaching experiences to see what activities or instructional methods changed (for better or worse) their attitudes or beliefs about mathematics, when they occurred (i.e., in what course or experience), and why they were particularly effective.

Perseverance. Secondly, my results showed that even those who reported liking mathematics had many negative experiences to share in their autobiographies, survey responses, attitude graphs, and interviews. It seems that no one is immune to encountering battles during their mathematics journeys, and some of the likers' negative experiences were similar to the turning points or examples from dislikers that left them feeling a lasting dislike for mathematics. Future research should explore the negative experiences of those who like mathematics to try to understand what it is that helps them persevere and continue liking the subject through and despite the bad times.

Theory. The model I developed (Figure 8.1) shows some theorized connections between attitudes, beliefs, and experiences that were not thoroughly explored in this study. Namely, I did not explicitly explore how attitudes and beliefs affect experiences. I also am not certain of the necessity of experiences as a mediating factor in the double-sided arrow connecting attitudes and beliefs. Can attitudes change beliefs (or vice versa) without experiences (perhaps with emotions as a mediating factor, as theorized by McLeod, 1992)? I think of participants in the study who expressed the belief that mathematics consists of finding one answer or solution, and how that belief affected participants differently: Mathematics likers tended to value it while mathematics dislikers did not. Hence, I recommend future research explores the ways attitudes and beliefs affect each other in ways that were beyond the scope of this study.

Research Methods. Researchers may have accepted the general lesson that PSTs tend to dislike mathematics and have mathematics anxiety based on prior research results from attitude scales first developed in the 1970s and 1980s. My population had relatively few participants who indicated disliking mathematics, albeit in response to one Likert-scale item and a follow-up open-ended response item. Perhaps it is time to develop new scales and test the accepted theory that PSTs do still tend to dislike mathematics. Perhaps something has changed in teacher preparation, in the teacher education standards in recent years, or time has resulted in improved attitudes toward mathematics. I recommend developing a more open-ended approach to their understanding as well, as my participants also reported different meanings for their attitude rating (e.g., most recent feeling, average of feelings over time).

Lastly, in response to seeing how the beliefs of my participants tended to change over time, I recommend that researchers develop a sort of "beliefs timeline" activity for students to complete as a means for gaining information about when and how their beliefs shift over time. Participants would need to understand the meaning of beliefs about mathematics and perhaps be given a list of possibilities (not unlike those developed in this study). They could then indicate their beliefs on the timeline and describe the events that may have informed the development of those beliefs.

Conclusion

In conclusion, the role people's experiences play have great impact on both their attitudes toward, and beliefs about mathematics. Though my particular sample was drawn from a population of prospective elementary teachers, the experiences they shared and were described in this study are familiar to many. I see the three – experiences, attitudes, and beliefs – as intimately connected. Though I have found through this study many new ideas about how those who like and dislike mathematics view it differently and come with their own unique stories, I am left wondering about the connections between the three concepts. For instance, why is it that certain people tend to persevere in their attitudes and beliefs through negative experiences while others do not? How do attitudes and beliefs directly affect each other (and how) or are experiences required as a mediating factor? How can those of us who are mathematics teacher educators use our courses as therapy for those who come with a devastating history with the subject we love while still growing the beliefs and further raising the attitudes of those who have different, more positive histories? How can we make room for such “recovery” work when there are so many demands placed on teacher education programs and teacher candidates?

My hope is that this research provides some insights that are useful in answering these important questions. My findings indicate the possibility of elementary mathematics education as a place for therapeutic reflection. In the future I hope we can see the development of such courses, along with other changes in teacher preparation at both elementary and secondary levels. I envision sending forth elementary teachers who both have improved attitudes about mathematics themselves and can thus promote them, along with healthy beliefs, in their own classrooms. I envision secondary and university mathematics instructors better understanding that they will teach students with varied (and often negative) histories with, attitudes toward, and beliefs about mathematics. And I hope that these understandings will allow for new approaches to be developed in mathematics instruction that allows more preservice elementary teachers to enter their programs on better terms with mathematics and in turn begin to break the cycle of instruction-impacted negative attitudes and beliefs about mathematics.

APPENDICES

APPENDIX A

Pre-Writing Questionnaire

Name: ________________________

Gender: ☐ Male ☐ Female ☐ Other: _____________

Age: _______________

Year in School: ☐ Freshman ☐ Sophomore

☐ Junior ☐ Senior ☐ Other: _____________

Last Mathematics Class Taken: _____________________

Grade received in last mathematics class (ignoring +/-): ☐ A/4.0 ☐ B/3.0 ☐ C/2.0 ☐ D/1.0 ☐ F/0.0

Major(s) of Study: __________________

Minor(s) of Study: __________________

APPENDIX B

Mathematics Autobiography Prompt

For the essay, please write your mathematics autobiography titled: "Me and Mathematics: My Relationship with Mathematics." Please reflect on and write about your experiences with mathematics (in school and out of school) prior to taking this course. This prompt is purposefully vague so that you write about the experiences that most informed, shaped, or changed your relationship with mathematics as you remember them. Include any major turning points, if any, in your relationship with mathematics but also include experiences that kept you where you were at. Go as far back in your memories as you can until the present time.

APPENDIX C

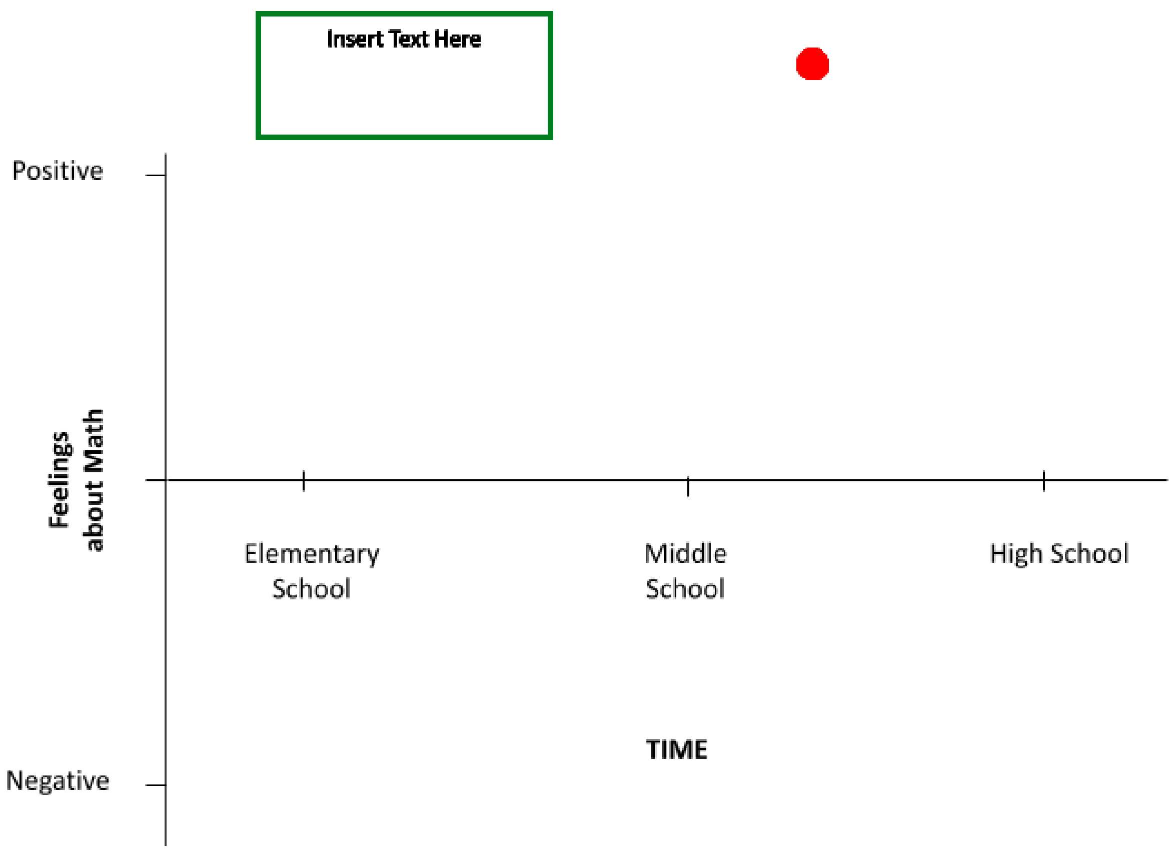
Attitude Graph

Please indicate your feelings about mathematics based on your experiences across your time before college.

The X-axis (horizontal) represents **time**, from birth until you entered college. Elementary, Middle, and High school are labeled as a guide, but you may find you plot more significant points and events in one area more than others.

The Y-axis (vertical) represents your **feelings about mathematics (or attitude toward mathematics)**. Think of the highest mark as indicating very positive feelings or liking mathematics; the middle mark as indicating indifferent feelings, and the lower mark as very negative feelings, or strongly disliking mathematics. If there were any events that caused you to change your feelings or attitude, make sure those are indicated.

MY FEELINGS ABOUT MATHEMATICS



APPENDIX D

Interview Protocol

Set up: Why are we here?
You're here because I have a strong interest in understanding better why someone might like or dislike mathematics. The more open you are about your experiences in mathematics, the better it will be for my research and for trying to find ways to make a positive impact on the kinds of experiences you and other preservice teachers might have in mathematics in the future.

Background information
1. Where did you grow up?

2. Where have you gone to school? Can you tell me what those schools were like?

Attitude Graph
3. So you wrote an autobiography for me. I'd like you to take a little time to re-read it, because afterward, I'm going to have you create a little graph or timeline for me so I can have more of a visual of events in your life that may have affected whether you like or dislike mathematics. It also hopefully will help you to think more about moments where it wasn't all bad or moments where there was some sort of turning point for you, either for the better or worse. So I'd like you to annotate the autobiography if you have moments from there you'd like to put on the timeline afterward, and any others you might think are good talking points about which to go a little deeper. After you re-read it, I'd like you to go ahead and start making a timeline. Just let me know when you're done, and I can explain the timeline further. (intro graph after, give option of points, smooth curve)

4. Is there any experience on the graph you made that seem to be the most significant in influencing how you feel about mathematics? Do you have anything that you see as a turning point?

Attitude and Beliefs Prompts follow-up

5. You also filled out some prompts for me. I would like you to review your answers to (list certain questions) briefly, and then I will ask for some clarification or expansion on them.

(Prompt-response dependent conversation here)

6. I asked how you see mathematics as similar or different from other subjects – but let's talk more broadly to general human behavior. How does mathematics fit with the way the world works – does it fit? (to help, I could ask if they think it comes naturally out of how the world works or do they think it's something we've just created to help us think logically, or is it something else entirely)
7. Tell me about your favorite teachers. Were any of them mathematics teachers? If not, what were your mathematics teachers like?

APPENDIX E

Survey Question 2 Responses for Those with "Complex" Attitudes

Participant Number	Survey Q1 Rating	Reason for Rating
3	5	My experience with Mathematics 201 and 202 at MSU. Before I had [these instructors], my answer would've been 2-3. Even when I'm struggling these days, I'm confident I have people who will help me better understand what it happening.
35	4	I sometimes have doubt about some of my answers due to being anxious/nervous.
101	4	There is too much HW
111	4	I have had some very good experiences with mathematics, but I have also had a few rough ones. My liking of mathematics really depends on the topic being covered. I prefer algebra over geometry, but prefer geometry over calculus.
24	3	I like the simple mathematics and teaching it to younger kids but, I would not like to teach high school mathematics.
36	3	i really not good at test
40	3	I have always struggled in mathematics and would always have a difficult time keeping a high grade in the class since concepts at times were hard to grasp.
41	3	Mathematics has never come easily to me. I am always the last one to understand something and the one that always needs extra help. I have also never found mathematics very interesting.
60	3	I have had a lot of mathematics teachers that have made me love mathematics less and less over the years. I have never been super great at it, so I have to work a lot harder than any of my other subjects. That paired with the okay teaching over the years has made me like it less and less.
82	3	It is hard! It takes me a long time to understand.
90	3	I don't really enjoy doing it, and I have struggled with it in the past
92	3	Mathematics is the subject I've always had the most struggles with. My confidence in the subject is low.
102	3	It's always been a struggle for me.
104	3	It is sometimes hard to find why it is applicable to my life

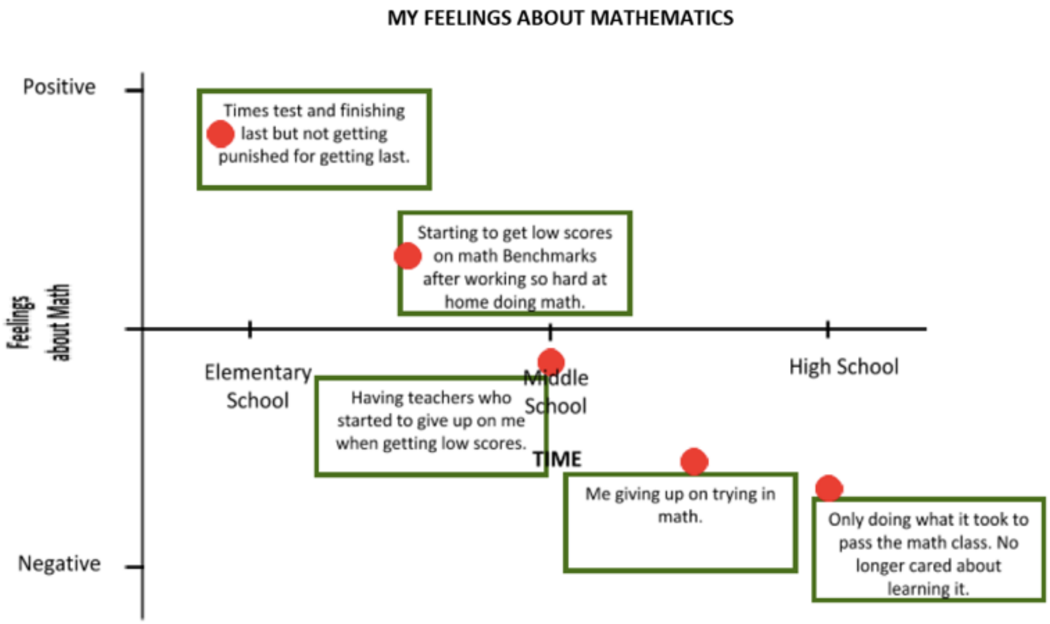
APPENDIX F

Interview Participant Attitude Graphs

(sorted by Attitude Rating level)

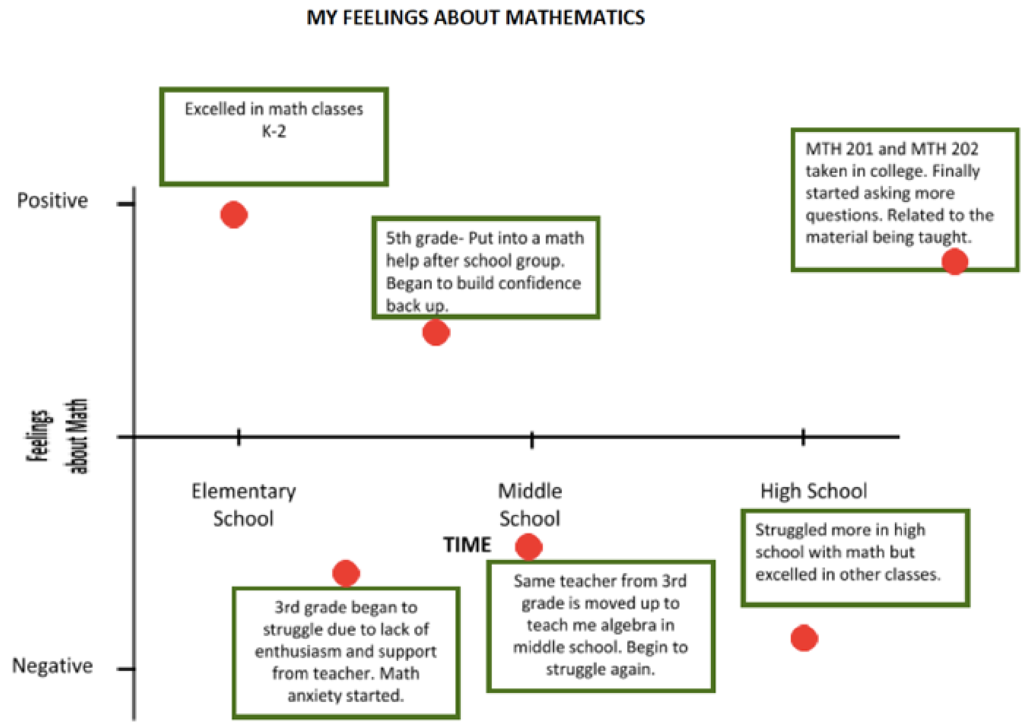
1-"Strongly Dislike"

Participant 1

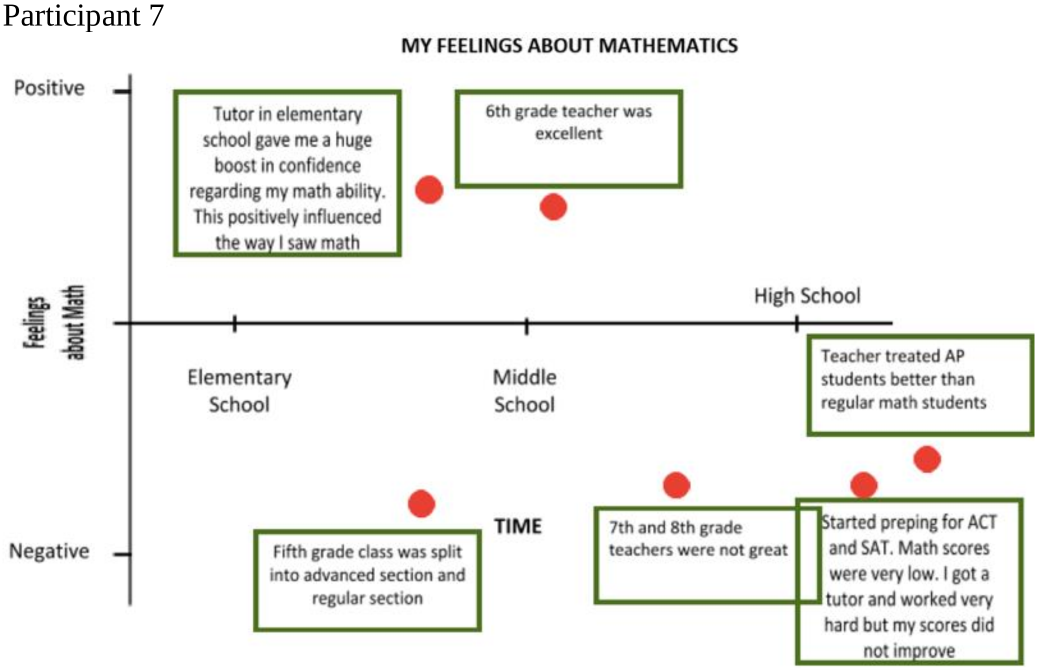


2-“Dislike”

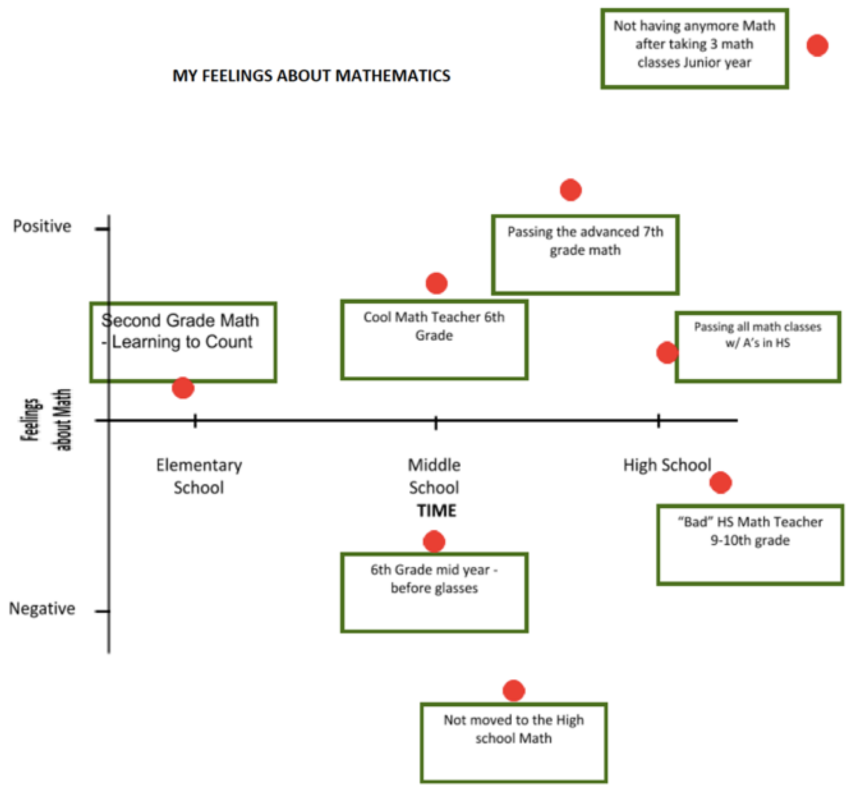
Participant 6



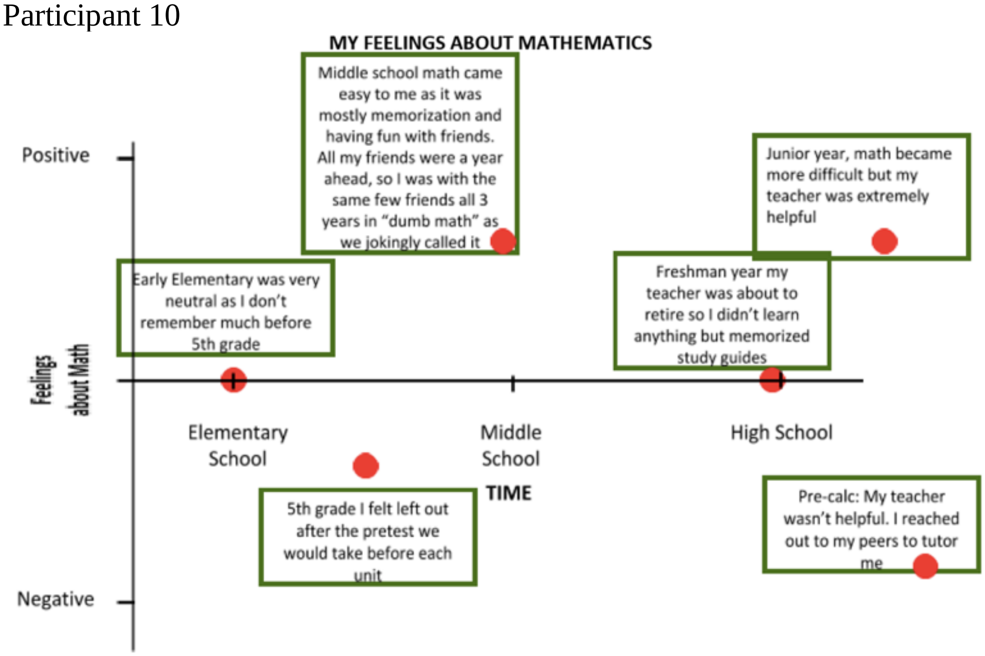
Participant 7



Participant 8

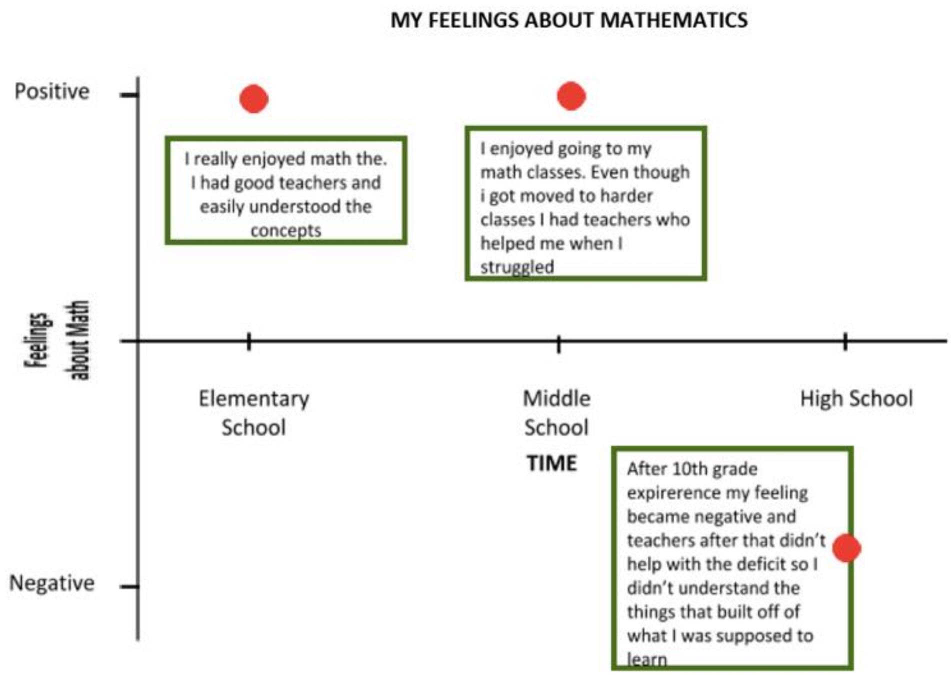


Participant 10

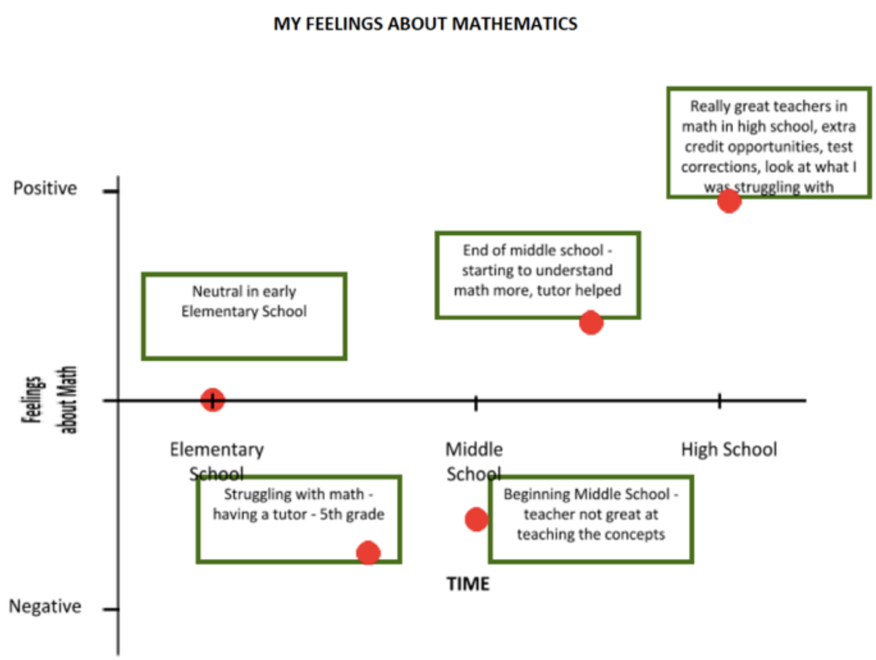


3-"Neutral"

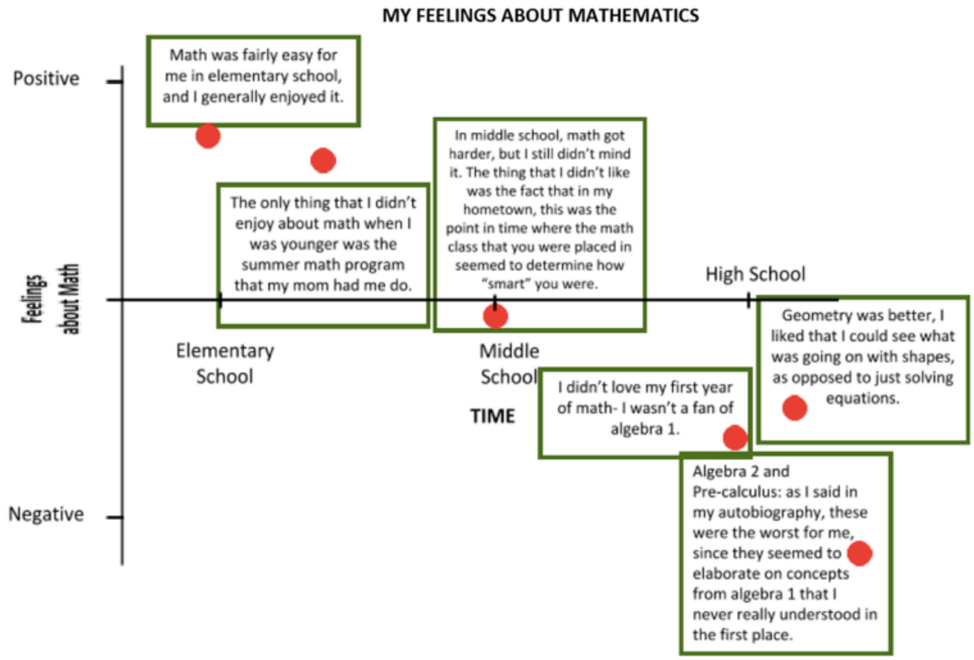
Participant 12



Participant 13

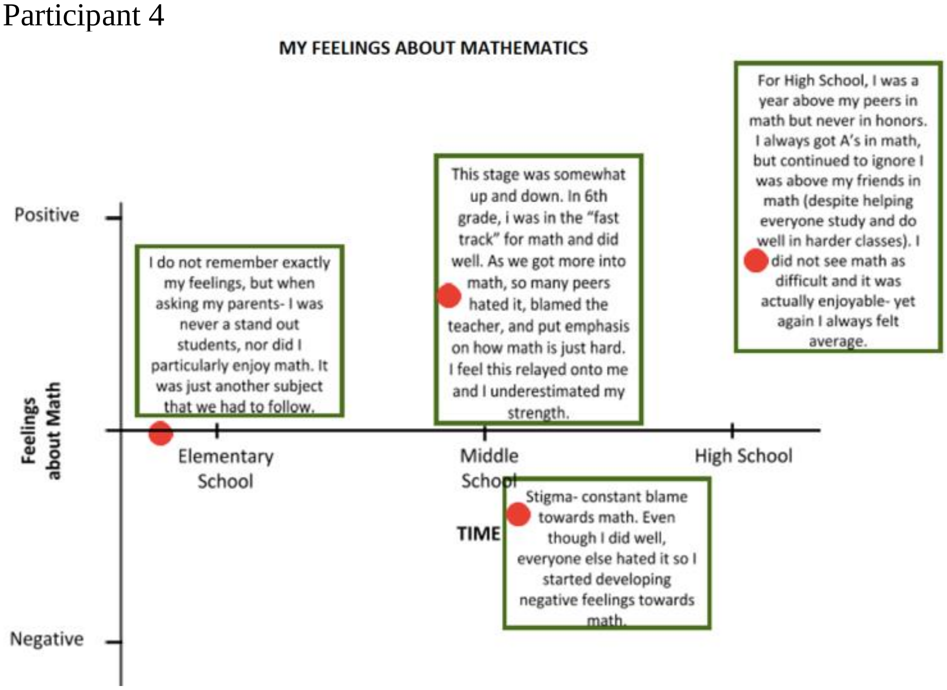


Participant 14

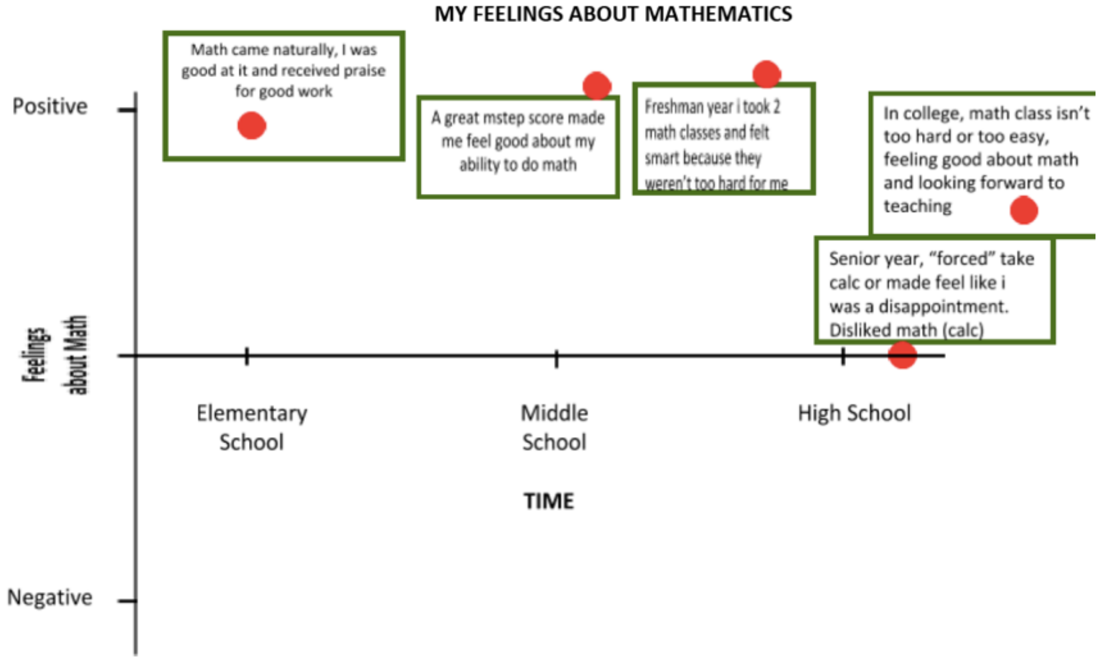


4-"Like"

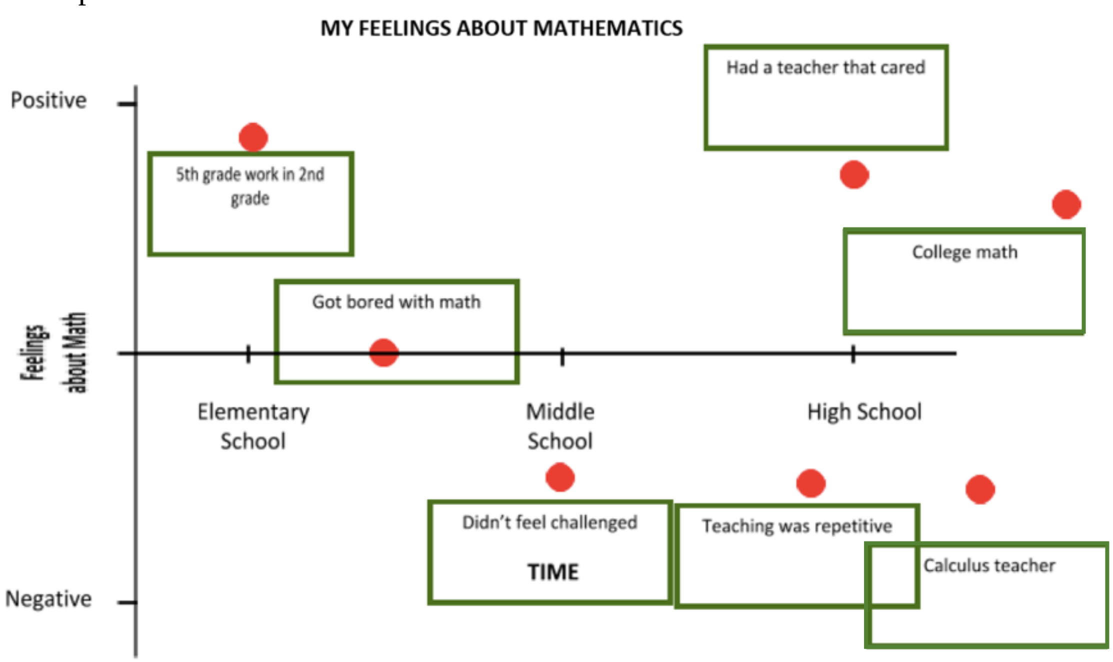
Participant 4



Participant 9

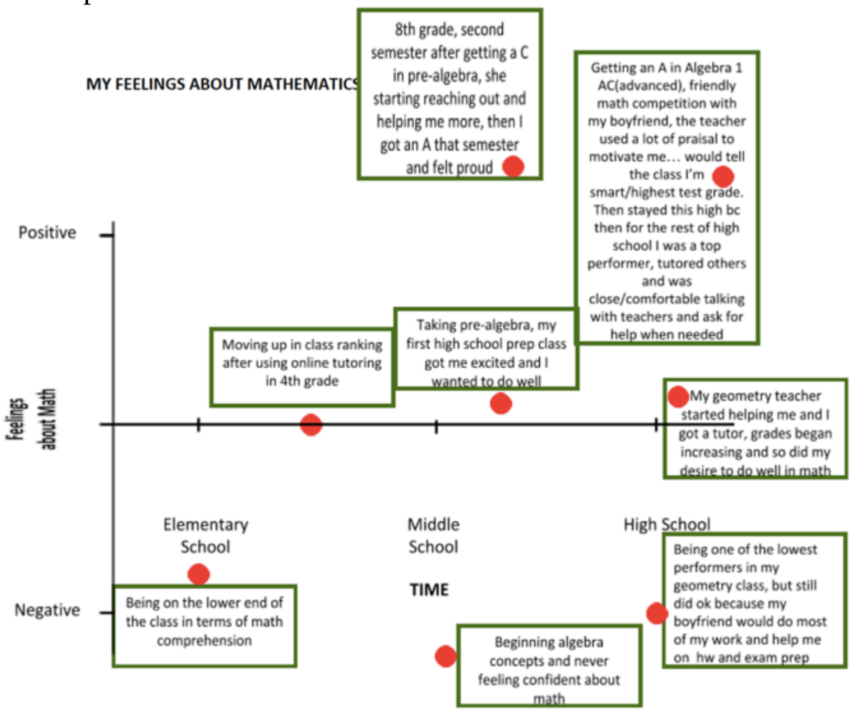


Participant 11

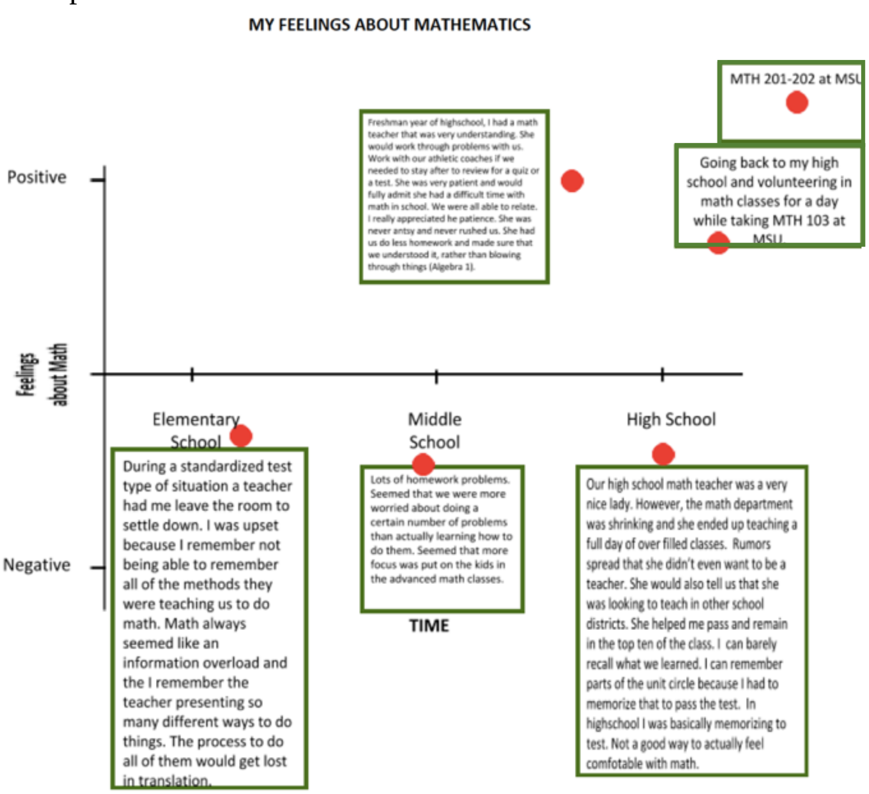


5-“Strongly Like”

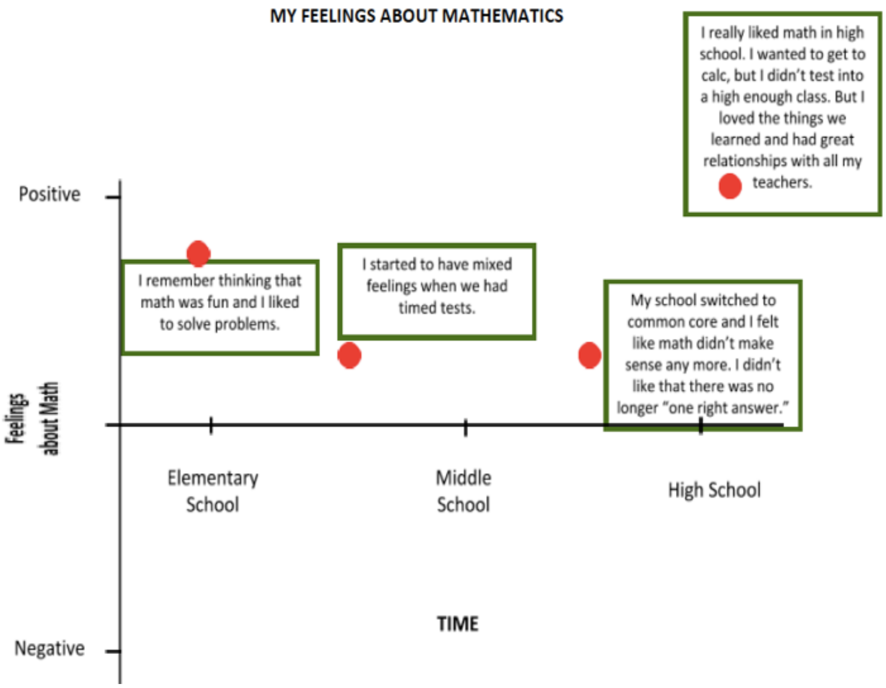
Participant 2



Participant 3



Participant 5



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