The Manifestation of Elementary Teachers’ Mathematical Identities: An Explanatory Mixed Methods Study

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The Manifestation of Elementary Teachers’ Mathematical Identities: An Explanatory Mixed Methods Study

A Dissertation Presented to the Faculty of the
Department of College of Education and Social Work
West Chester University
West Chester, PA

In Partial Fulfillment of the Requirements for
The Degree of Doctor of Education

By
Kyle W. Brun

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Dedication

I would like to dedicate this dissertation to the exceptional elementary educators who answered the call to put themselves in the service of their students. Their dedication to the craft of teaching and commitment to their students is unmatched. I am inspired by the love and compassion you share with every child year after year. Each day you are called to make a difference in the lives of so many children and I thank you for answering the call!
Acknowledgments

This journey would not have been possible without the help of my faculty advisor Dr. Mimi Staulters who helped guide and support me throughout the process. Her mentorship and support helped me persevere in the face of what felt like insurmountable obstacles. I would also like to acknowledge Dr. Van Schooneveld and Dr. Bowen who graciously served on my dissertation committee giving up their time to provide guidance and feedback along the way.

To my family, your constant love and support means the world to me. To my wife Julie, you carried a burden that was unfair of me to ask and did so with love and compassion. This was not possible without your support and for that I am forever thankful! To my children, Joseph, Isabella, Samantha, and Dominic, your encouragement and patience did not go unnoticed. Thank you for being amazing, supportive, and understanding!

I would like to acknowledge all of the members of Cohort 6! For all of the long nights, laughter, doubt, and phone calls, it is amazing that we get to finally say we made it. Thank you for the support that got me through the tough times and for sharing in the joy of this accomplishment.

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Abstract

In the most simplistic form, mathematical identities manifest in the statements, “I am good at math” or “I am not good at math”. Once established, individuals’ identities influence how they interact and approach mathematical problem-solving (Bishop, 2012; Boaler, 2013; Boaler & Selling, 2017). The purpose of this mixed-method explanatory sequential study is to explore a deeper understanding of how elementary teachers’ mathematical identities influence their beliefs about effective math instruction. Utilizing an explanatory sequential mixed-method design, a questionnaire was used for the initial quantitative analysis of teachers' mathematical identities. Analysis of survey submissions identified three unique mathematical identity profiles. Two representatives from each of the profiles participated in qualitative semi-structured interviews. Participants in the survey were limited to elementary-certified math teachers in eight public school districts in Southeastern Pennsylvania. Forty-eight teachers completed the initial questionnaire, and six individuals participated in follow-up interviews. Using SPSS, descriptive and categorical statistical analysis was conducted to correlate participants’ current mathematical identity with their beliefs about mathematical instructional practices. Interview transcripts were coded and analyzed for themes to add additional context and rich description to the initial quantitative findings. The study found that teachers past experiences significantly influence the development of their math identities which are dynamic and complex in nature. Furthermore, individuals with a more negative mathematical identity prefer more traditional math instructional practices and value solutions to problems over the process of learning mathematics.

Keywords: Mathematical identity, mixed methods, elementary mathematics
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A persistent challenge exists within American education; students’ mathematical achievement consistently lags behind their peers in advanced industrial nations (Desliver, 2017). Additionally alarming is the growing gap between our students’ progress in mathematics and their achievements in English language arts and science performance, as demonstrated in the results of the Programme for International Student Assessment (PISA) (Desliver, 2017). In a longitudinal analysis of the PISA assessment, the Pew Research Center found that minimal to no mathematical achievement growth was observed among cohorts of U.S. 4th and 8th-grade students from 2005 through 2015 (Desliver, 2017). The Pew Research Center’s findings highlight the challenge faced in math classrooms nationwide and indicate that traditional efforts to reform mathematical programming have not resulted in measurable improvement in US students’ mathematical achievement over time. This challenge is not an isolated problem; state and local educational agencies also experience this phenomenon. For example, in Pennsylvania, only 35.7% of all 3rd through 11th-grade students achieved the minimum benchmark level of proficiency as measured by the 2022 Pennsylvania School System of Assessment (PSSA) and Pennsylvania Keystone exams (PA Department of Education, 2022).

Unsurprisingly, educational institutions and researchers have dedicated significant resources and time to dissecting and understanding the challenges and barriers preventing US schools from maximizing students’ mathematical growth and achievement. The National Council of Teachers of Mathematics (NCTM), the premier professional organization dedicated to the improvement of math education in the United States, has published a series of documents aimed at identifying and dismantling the barriers that hinder our students’ mathematical potential and achievement (National Council of Teachers of Mathematics (NCTM), 2018; NCTM, 2020a;
As a result, an era of mathematical reform has called for pedagogical and instructional shifts that emphasize the development of skills in problem-solving, reasoning, modeling mathematical concepts, and applying mathematical skills in real-world contexts (Karatas et al., 2022). The call for mathematics educational reform has catalyzed academic researchers to explore diverse perspectives and solutions that may help maximize student mathematical achievement in America (NCTM, 2018; NCTM, 2020a; NCTM, 2020b).

Among the research, an emergent area of interest centers on the significant connection between individuals' beliefs about their mathematical abilities, known as mathematical identity, and their academic growth and achievement (Aguirre et al., 2013; Cross francis, 2014; Boaler, 2013; Boaler & Selling, 2017). The link between promoting a positive mathematical identity in students to maximize their achievement and growth is well established (Aguirre et al., 2013; Cross francis, 2014; Boaler, 2013; Boaler & Selling, 2017), and researchers have explored cultural and social interactions' influence on forming individuals’ mathematical identities (Cobb et al., 2009; Esmonde, 2009; Langer-Osuna, 2011; Wood, 2013). Links exist between sociocultural factors, such as communication/dialogue (Cobb et al., 2009; Langer-Osuna, 2011), peer-to-peer interactions (Cobb et al., 2009; Esmonde, 2009), teacher-to-student interactions (Esmonde, 2009; Wood, 2013), and power dynamics (Esmonde, 2009) that exist within classroom settings and the development of personal beliefs about ability and skills. Research into mathematical identity sheds light on the importance of establishing inclusive and supportive classroom environments to foster positive mathematical identities, leading to increased student growth and achievement.

A substantial gap exists in this area because prior research has yet to comprehensively explain how teachers’ mathematical identities shape their beliefs about effective mathematical
practices (Darragh, 2016; Graven & Heyd-Metzuyanim, 2019). This gap emphasizes the necessity of conducting research to explore how teachers develop their mathematical identities and how these identities influence their beliefs about effective instructional practices. Chapter one will present the purpose of the dissertation’s study, including the problem statement, rationale, and research questions. The chapter will also provide definitions of essential vocabulary and discuss the study's limitations associated with the researcher’s positionality.

**Purpose of the Study**

This research study aims to explore a deeper understanding of how elementary teachers’ mathematical identities affect their beliefs about effective math instruction and support the development of a positive mathematical identity in their classroom. An explanatory sequential mixed methods design was used to collect quantitative data and then explain the quantitative results with in-depth qualitative analysis. In the first quantitative phase of the study, questionnaire data was collected from elementary mathematics teachers from Southeast Pennsylvania public schools to test sociocultural theory and assess whether teachers’ mathematical identities relate to their beliefs about their students’ mathematical abilities and inform their instructional choices. The second qualitative phase was conducted as a follow-up to the quantitative results to help explain the manifestation of teachers' identities in their beliefs about teaching math. In this exploratory follow-up, the study explored the development and manifestation of mathematical identities among elementary math teachers from eight public schools in Southeast Pennsylvania.

This study addresses a gap in the research regarding how elementary teachers’ mathematical identities evolve and how their mathematical identities influence their instructional practices and beliefs about their students’ mathematical abilities. Elementary math teachers will
benefit from this study by understanding how their personal beliefs could influence and affect their ability to maximize student achievement and growth. In addition, the results of this study will help teachers identify how their own mathematical identity may be influencing the development of a positive mathematical identity in their students and informing their preferences for instructional practices. Finally, this research will inform the field of math education by providing districts and universities insight into professional development and teacher preparation programs that effectively identify and promote positive mathematical identities in educators.

**Rationale for Study**

Sfard and Prusak (2005) define mathematical identity as a “set of reifying, significant, endorsable stories about a person” (p. 14). Boaler and Greeno (2000) find that the context in which individuals engage in mathematical practice as students significantly shapes the development of their mathematical identity. Students who develop positive mathematical identities develop the ability to make sense of and use math to solve problems, value the process of problem-solving and the answer, and enjoy collaboration (Boaler, 2013). In contrast, students who develop negative mathematical identities struggle to persevere when faced with mathematical challenges and value the answer over the process of learning (Boaler & Selling, 2017).

Elementary mathematics teachers are responsible for fostering and developing positive mathematical identities in their students. However, many elementary teachers still need to develop their own positive mathematical beliefs, affecting how they teach math to students. Recent publications have explored the role of teachers’ mathematical beliefs in fostering a positive student identity (Aguirre et al., 2013; Cross francis, 2014; Lutovac & Kaasila, 2017). Cross francis (2014) found that teachers' beliefs about mathematics influence how they instruct
students. These beliefs are complex and can be changed. Aguirre et al. (2013) identify that teachers who develop an awareness of their mathematical identity can better adapt instructional practices that promote positive math beliefs in their students.

The link between promoting a positive mathematical identity in students to maximize their achievement and growth is well established (Aguirre et al., 2013; Cross Francis, 2014; Boaler, 2013; Boaler & Selling, 2017). However, there is a gap in the research regarding how elementary teachers’ mathematical identities evolve and how their mathematical identities influence their instructional practices and beliefs about their students’ mathematical abilities. This explanatory sequential mixed-methods research plan investigates the relationship between elementary teachers’ mathematical identity and their instructional beliefs. It explores a deeper understanding of how elementary teachers’ mathematical identities affect how they deliver math instruction to their students and support the development of a positive mathematical identity in their classroom.

**Problem Statement**

It is a heartbreaking experience for a teacher to hear a child say I am not good at math. Nevertheless, this phrase is common in classrooms across America. Research has shown that students’ experiences in the classroom communicate messages that develop and reify the personal narratives that end up becoming part of the student’s identity as a mathematician (Langer-Osuna, 2011; Sfard & Prusak, 2005; Turner et al., 2013) Once established, these narratives have a significant influence on how individuals engage with and process mathematics (Boaler, 2013; Boaler & Greeno, 2000). Insight into this phenomenon leaves researchers wondering: Can learning more about how students develop their mathematical identity be the
key to unlocking their true potential that ultimately helps address the observed underachievement in mathematics?

The current problem that mathematics education faces is addressing the persistently low mathematical achievement levels among American students. Efforts to improve mathematics instruction have yet to improve student achievement significantly (Desliver, 2017; NCTM, 2018). In Pennsylvania, school districts grapple with low proficiency rates in mathematics, and math achievement lags significantly behind achievement in English language arts and science (PA Department of Education, 2022). Unfortunately, these trends start early, and the data show that these significant mathematical achievement gaps start to develop at the elementary level (PA Department of Education, 2022; NCTM, 2022a).

Teachers and administrators face the challenge of addressing this problem and raising mathematical achievement levels. Students confront the challenge of growing their mathematical understanding in a way that unlocks potential future college and career opportunities. Researchers face the challenge of dissecting the problem to understand the root causes and possible solutions to the mathematical achievement gap. In light of these ongoing challenges, the problem is for researchers to understand better how mathematical identities may influence the ability to unlock a student’s mathematical potential and ultimately produce higher-achieving mathematicians. Although prior research recognizes the importance of fostering positive mathematical identities in students (Boaler & Selling, 2017; Boaler & Staples, 2008; Langer-Osuna, 2011), the connection between teachers' mathematical identities and instructional choices remains inadequately understood. Addressing this problem is crucial to enhancing mathematics education and maximizing student achievement and growth.
Through an explanatory sequential mixed methods approach, this dissertation seeks to explore the complex relationship between elementary teachers’ mathematical identities and their instructional beliefs. By investigating how these identities evolve and impact pedagogical choices, this study aims to explain how to foster the development of positive mathematical identities in elementary classrooms and contribute valuable insights to mathematics education. Furthermore, this study will address the need to comprehensively understand how elementary teachers' mathematical identities shape their instructional practices and beliefs, ultimately influencing the development of positive mathematical identities in their students. Addressing this problem is a crucial step for improving mathematics education and tackling the persistent challenges faced in math education.

Research Questions

The following research questions explore mathematical identity and its impact on elementary teachers’ beliefs about math instruction. This study utilizes an explanatory sequential mixed-methods approach to investigate how an elementary teacher’s self-reported mathematical identity affects their beliefs about effective math instruction delivery methods. Following a mixed-method design, the study will initially explore the research question through two quantitative sub questions and then address three qualitative sub questions (Creswell & Plano Clark, 2018).

Mixed Method Research Questions

1. How does an elementary teacher’s mathematical identity affect their self-reported beliefs about effective math instruction?
Quantitative Research Questions

1. What percent of educators surveyed report developing a positive versus negative mathematical identities?

2. Is there a relationship between the reported demographics of teachers and their self-identified mathematical identities?

These quantitative research questions directly contribute to understanding the quantitative aspect of the relationship between mathematical identity and instructional beliefs. Question one seeks to quantify the prevalence of positive and negative mathematical identities among educators. Question two explores potential relationship between demographics and mathematical identities. It is anticipated that analysis of survey data will show a relationship exists between teachers who have developed positive mathematical identities and specific demographic markers such as age.

Hypothesis. A relationship does exist between a teacher’s self-reported mathematical identity and their reported demographics.

Null Hypothesis. A relationship does not exist between a teacher’s self-reported mathematical identity and their reported demographics.

Qualitative Research Questions

1. How are teachers’ mathematical identities influenced by their experiences as math students and educators?

2. How do teachers’ mathematical identities align with their preferences for instructional choices?

3. What beliefs do teachers report about the importance of learning math, and how does this relate to the teachers’ mathematical identities?
These qualitative research questions delve into the aspects of mathematical identity related to its impact on instructional choices. These questions explore teachers' beliefs and practices' complex, contextual, and nuanced aspects. It is expected that teachers who have developed a positive mathematical identity value the use of instructional strategies that promote collaborative, dialogic, problem-based learning experiences.

**The Rationale for the Methods**

This study utilizes an explanatory sequential mixed-methods design completed in two phases. A mixed-methods design is appropriate because the complexity of the problem requires investigation beyond solely what a quantitative statistical analysis or a qualitative description can provide (Creswell & Plano-Clark, 2017). Furthermore, an explanatory sequential mixed-methods design is well suited to use qualitative data to explain initial quantitative data's findings or lack of significance (Creswell & Plano-Clark, 2017). Explanatory sequential was chosen for this research because the initial quantitative phase allows for the identification of unique mathematical identity profiles that will be compared and explored in greater depth during the qualitative phase of the study. A sequential core design allows the construction of participant identity profiles from the initial quantitative results followed by a qualitative phase, which provides greater depth and description (Creswell & Plano-Clark, 2017, p.199).

Previous research exploring mathematical identities has relied heavily on studies employing a qualitative approach that often includes a sample size of less than ten participants (Darragh, 2016; Graven & Heyd-Metzuyanim, 2019). Although uncommon, Graven and Heyd-Metzuyanim (2019) identified two fundamental studies that incorporated quantitative data collection within their methodology. Mathematical identity research has gained popularity in recent years (Darragh, 2016; Graven & Heyd-Metzuyanim, 2019; Radovic et al., 2018);
however, due to small participant size, additional studies are needed to identify and explain the contexts in which mathematical identities form, are identified, and manifest in practice. Utilizing an explanatory sequential mixed-methods design for this study allows for the use of established qualitative study practices from previous mathematical identity research to explain quantitative data that relates elementary teachers’ identities with their beliefs about effecting teaching practices in a mathematics classroom.

**Significance of Study**

There is a movement supported by the National Council of Teachers of Mathematics (NCTM) to engage students in more collaborative dialogic problem-solving learning activities (NCTM, 2018; NCTM, 2020a; NCTM, 2020b). Students who engage in rich mathematical discourse construct deeper conceptual understandings and can better apply their knowledge outside the traditional math classroom (Boaler & Selling, 2017). However, one identified challenge to successfully implementing this teaching philosophy is students with a fixed mathematical mindset or the belief that they are not good at mathematics (NCTM, 2018). This negative identity is constructed over time and manifests in students' hesitancy to engage in productive struggle and collaborative problem-solving (Boaler & Selling, 2017). In addition, the teacher’s mathematical identity plays a significant role in their ability to support students' construction and active participation in developing positive mathematical beliefs (Aguirre et al., 2013; Boaler & Staples, 2008). The link between promoting a positive mathematical identity in students to maximize their achievement and growth is well established (Aguirre et al., 2013; Cross francis, 2014; Boaler, 2013; Boaler & Selling, 2017).

There is a gap in the research regarding how elementary teachers’ mathematical identities evolve and how teachers’ mathematical identities influence their instructional practices and
beliefs about their students’ mathematical abilities. Current mathematical identity research demonstrates a bias for investigating students over teachers (Darragh, 2016; Graven & Heyd-Metzuyanim, 2019). Furthermore, because of the small sample sizes included in most identity research, 58% of studies reported fewer than ten participants, the need exists to investigate the topic further (Darragh, 2016, p. 23).

Elementary math teachers will benefit from this study by understanding how their personal beliefs could influence and affect their ability to maximize student achievement and growth. In addition, the results of this study will help these teachers identify how their own mathematical identity may be influencing the development of a positive mathematical identity in their students.

**Researcher’s Positionality**

As a mathematics supervisor, I am tasked with establishing systems and structures to maximize student achievement and growth. In this role, I make decisions and provide opportunities to support students by providing the best possible mathematics programming. However, in my experiences working with teachers, I have observed fear, stress, and hesitancy often manifesting when they learn and implement new strategies in their math classrooms. These feelings are widespread at the elementary level, where teachers have said, “That is not how I learned math” and “I was never good at math.” My interactions with elementary teachers have uncovered that teachers' experiences as math students can hinder their confidence and beliefs about instruction in the classroom. I believe that removing these barriers is essential to my role in supporting teachers and ultimately providing the best possible mathematics education for students.
My research focuses on the manifestation of elementary math teachers’ mathematical identities in their beliefs about effective instructional practices and perceptions about how their students best learn math. In my role, I am interested in learning how to best address and support teachers who believe they may not have the skills to deliver a math curriculum based on problem-solving, collaboration, and responsive teaching over traditional procedural-based instruction. As a supervisor, I have made it my mission to foster a culture where everyone believes they can make sense of and persevere in mathematics.

My professional role affords me the forum to influence and guide my district’s elementary math programming. As a result, my positionality creates specific ethical dilemmas. I am a male administrator entering an environment dominated by female teachers. Therefore, I hold a position of power and authority over the practitioners who have dedicated their lives to educating our youngest learners. I have to be vigilant of my beliefs about math instruction and ensure that they do not influence the participants in the study. Establishing trust and authenticity with participants is essential to the success of my research.

**Definition of Terms**

- **mathematical identity**: Individuals' beliefs about their math ability. Often, these take the form of personal narratives or stories individuals tell themselves (Sfard & Prusak, 2005).
- **sociocultural constructivism**: Individuals construct a sense of self and personal beliefs through social interactions and within the social constructs of communities (John-Steiner & Mahn, 1996).
- **macro vs. micro identities**: Individuals construct fluid micro identities in short-term experiences and interactions. Macro identities are reified over time and become more established beliefs individuals hold about themselves (Wood, 2013).
• **constructing knowledge**: Individuals make sense of abstract concepts by connecting them to prior experiences and making sense of the concepts within lived experiences. Constructing knowledge contrasts received knowledge or the belief that understanding is achieved through explicit knowledge transfer from the expert to the learner (John-Steiner & Mahn, 1996).

• **mathematical discourse**: The conversations that occur within a classroom relating to mathematics (Boaler & Staples, 2008).

• **mathematical reform movement**: A call to move mathematics education from a receiving knowledge model to a constructing knowledge model. The mathematical reform movement embraces constructivist ideology and dialectic teaching practices (NCTM, 2018).

**Limitations**

With all research that includes quantitative data collection, one major limitation is the accuracy of the representation of the participants compared to the population (Creswell & Guetterman, 2019). In this study, the number of initial participants must represent a large enough sample of the population in order to make generalizations. Furthermore, I include accurate descriptions of the participants' population to assist in generalization. Given the purposeful selection of teachers for interviews, using identified mathematical identities, the study recognizes and represents a more diverse range of identities to help address generalization limitations.

One potential limitation may arise if there are limited representative participants for each identified mathematical identity profile. The qualitative interviews rely on participants willing to engage in follow-up interviews and represent each of the profiles identified from the initial statistical analysis. To address this limitation, a wide net is cast by reaching out to teachers in
eight districts throughout southeastern Pennsylvania. The number of potential participants increases the likelihood of achieving a representative sample from each identified case profile. In addition, the qualitative second phase of the study provides detailed context and explains the findings from the quantitative phase (Creswell & Guetterman, 2019). Limited representative participation in phase 2 of the study creates an additional challenge in generalizing the context provided by the participants to a larger population. Two representatives from each identified profile group will be selected for follow-up interviews to address this concern. Coding and comparing data from two participants representing the same profile group allows for identifying common themes and supports the development of more generalizable conclusions (Saldaña, 2015).

An additional limitation of the study is the reliability of the findings outside of the participants’ districts. Inclusion criteria were carefully selected to address this concern and provide the specific context in which the study applies. In addition, this study relies on self-reported data, so the questionnaire must be straightforward with minimal room for variable interpretation. We influenced the questions by drawing from previously vetted questionnaires such as Op't Eynde and De Corte's (2003) survey to enhance survey reliability. Furthermore, educational colleagues vetted the questionnaire for the highest probability of clarity and validity before administration. However, the questionnaire has not been previously validated and has no reliability statistics to support its reliability.

Important to note are researcher limitations that are associated with a mixed-methods study. Competence in both quantitative and qualitative research practices strengthen mixed-methods research (Creswell & Guetterman, 2019). To support the mixed methods design, the study has identified straightforward quantitative and qualitative research questions and included
a hypothesis and null hypothesis to aid in examining the quantitative research phase of the study. Additional efforts to increase the validity of the study's qualitative phase include using multiple rounds of coding and identifying commonalities and thematic categories (Saldaña, 2015).

**Summary**

This chapter provides an overview of American education's complex challenges in mathematics. It highlights the persistent gap in mathematical achievement between American students and their peers in advanced industrial nations. Furthermore, it identifies the growing disparity in student achievement between mathematics and other subjects. As a result, the National Council of Teachers of Mathematics (NCTM) has called for reform emphasizing problem-solving, reasoning, and real-world application. Within this context, researchers have identified a link between developing positive mathematical identities and maximizing student achievement and growth (Aguirre et al., 2013; Cross francis, 2014; Boaler, 2013; Boaler & Selling, 2017). However, the development of mathematical identities is complex, and as a result, we need additional research to understand how teachers' mathematical identities develop and influence their practice as educators (Darragh, 2016).

The rationale for the study is grounded in the need to address persistently low mathematical achievement levels, particularly among American students. The chapter argues that elementary teachers play a crucial role in fostering positive mathematical identities in their students but may face challenges related to their mathematical beliefs. Therefore, understanding the link between teachers' mathematical identities and instructional choices is essential.

To address these critical issues and provide deeper context, Chapter 2 explores the existing body of literature. In Chapter 2, the mathematical reform movement's historical context will clarify the current goals for math education reform. In addition, the literature review
provides an in-depth analysis of mathematical identity research and the challenges associated with studying mathematical identities. Finally, chapter 2 will explore the sociocultural influences, such as race and gender, on developing an individual’s mathematical identity. The chapter will present previous research findings to offer a comprehensive view of the context and theoretical framework that underpins this study.
Chapter 2

A Review of the Literature

As a subject of study and an educational field, mathematics profoundly impacts individuals' lives and educational journeys. It shapes cognitive development, personal beliefs, and perceptions about one's abilities and self-worth (Bishop, 2012; Boaler, 2013). At the heart of this intricate relationship lies the concept of mathematical identity, a multifaceted construct that has garnered increasing attention from researchers and educators in recent years (Darragh, 2016; Graven & Heyd-Metzuyanim, 2019). Understanding mathematical identity requires peering into the intricate web of sociocultural influences that shape how individuals see themselves as mathematicians (Boaler & Greeno, 2000; Sfard & Prusak, 2005).

The study of mathematical identities presents a pervasive challenge that centers on the elusive nature of defining mathematical identity. Scholars have highlighted the challenge of providing clear and universally accepted definitions, leading to findings that are often ambiguous and difficult to generalize (Bishop, 2012; Sfard & Prusak, 2005; Wood, 2013). This challenge is exasperated by the surge in mathematical identity research over the past fifteen years, marked by a substantial increase in published articles since 2008 (Darragh, 2016). To appreciate the depth of this research, this literature review will provide a unifying definition and framework for studying mathematical identities and delve into the historical context, which reveals a paradigm shift in mathematics education and identity research.

Furthermore, unpacking the sociocultural nature of math education uncovers intricate relationships between individuals' mathematical identities and the sociocultural context in which they develop. This literature review examines constructivist ideologies that emphasize the role of social interactions in shaping mathematical identities. In addition, this chapter will uncover the
manifestation of sociocultural inequities and their impact on developing positive mathematical beliefs.

An essential aspect of conducting mathematical identity research is recognizing and presenting the challenges associated with the topic. This chapter will analyze the common challenges identified in the literature and provide a theoretical framework that aligns with Vygotsky’s sociocultural theory of learning and Sfard and Prusak’s mathematical identity theory. Finally, this chapter will present the implications for teachers, including developing and manifesting their beliefs and their role in fostering classroom communities that promote positive student identities.

**Defining Mathematical Identity**

A challenge commonly associated with studying mathematical identities is articulating and framing the definition of mathematical identity (Bishop, 2012; Sfard & Prusak, 2005; Wood, 2013). Critics of mathematical identity research argue that the lack of clear definitions often results in findings that are ambiguous and difficult to generalize (Bishop, 2012; Brubaker & Cooper, 2000; Cobb et al., 2009; Sfard & Prusak, 2005). In response, authors have attempted to frame their research by developing and presenting definitions for mathematical identity (Bishop, 2012; Boaler & Greeno, 2000; Sfard & Prusak, 2005; Varelas et al., 2012; Wood, 2013). However, a systematic review of mathematical identity studies found that researchers often approach mathematical identity research through contrasting paradigms, and as a result, incongruencies prevail (Radovic et al., 2018).

For example, Bishop (2012) observed two middle school students in a math classroom over thirteen days. Bishop (2012) collected student artifacts, conducted interviews, and observed discourse and interactions throughout the observations. Framing the study, Bishop (2012) defines
mathematical identity as an everchanging view of self-negotiated and formed within social contexts and informed by events, personal narratives, routines, and experiences (p. 38). This definition highlights the complexity of describing the dynamic concept of self-awareness and recognizes the development of personal perception through ongoing internal and external factors. Bishop’s (2012) definition of mathematical identity is the story that individuals tell themselves about their mathematical ability and, just like any other story, is influenced by the characters, events, and inner dialog that shape the main character’s persona. Bishop’s (2012) focus on the dynamic nature of mathematical identity construction is a crucial aspect of his definition.

In contrast, Boaler and Greeno (2000) suggest that mathematical identity is an individual's perception of mathematical ability that is shaped and developed over time through personal experiences. In a 2017 longitudinal study, Boaler and Selling revisited participants from an earlier case study of two schools that took different approaches to math education. The original study was conducted over three years and included 290 high school students from two schools in England (Boaler & Selling, 2017). The original study found that students who received more collaborative math instruction that valued problem-solving and discourse among classmates developed stronger positive mathematical identities than students who received a more traditional math program that emphasized teacher examples and practice problems (Boaler & Selling, 2017).

Boaler and Selling (2017) surveyed 63 of the original participants and conducted 20 follow-up interviews. They found that individuals who developed a positive mathematical identity maintained positive beliefs about their math ability and were more likely to work in STEM-related careers (Boaler and Selling, 2017). This example reinforces Boaler and Greeno’s (2000) definition of identity and suggests that individuals follow a particular trajectory over time
in which they progress toward becoming. Like a journey with a particular destination, this view of mathematical identity posits that people are always working toward developing a specific view of self, ultimately leading to the belief that they are capable mathematicians or are bad at math.

The subtle nuances of each researcher’s interpretation lead to a lack of congruency in the definition of mathematical identity. Wood (2013) finds that the ideas of mathematical identities presented by Bishop (2012) and Boaler & Greeno (2000) are inadequate when considered independently. Wood (2013) argues that frequent shifts in beliefs about mathematical ability suggest that individuals are not permanently locked into a set pathway but rather develop more concrete personal mathematical identities as they make sense of experiences that shape/change short-term beliefs. Wood’s (2013) study included over 70 hours of observations of a group of fourth-grade students in an elementary math class. The researchers found that accumulating in-the-moment experiences shape an individual’s mathematical identity over time and, ultimately, constructs a broader understanding of self (Wood, 2013). Wood’s (2013) findings are rooted in a mathematical identity theoretical framework established by Sfard and Prusak (2005). Sfard and Prusak (2005) found that thinking of identity as a permanent notion of self that extends through time and experiences is problematic. Both Wood (2013) and Sfard and Prusak (2005) claim that mathematical identities can be dynamic in-the-moment constructs of mathematical self-confidence, which foster a long-term, reified personal belief about mathematical ability and competence.

Sfard and Prusak’s (2005) definition of identity provides the context and framework this literature review will use to unpack mathematical identity research. Sfard and Prusak (2005) define mathematical identity as a “set of reifying, significant, endorsable stories about a person.
These stories, even if individually told, are the products of a collective storytelling” (p. 14). This framework combines the social and dynamic nuances highlighted in Bishop’s (2012) study and the long-term growth and development of identity presented in Boaler and Greeno’s (2000) research. This combination of ideas provides a more comprehensive definition for conducting and framing mathematical identity research and, as a result, Sfard and Prusak’s (2005) definition of mathematical identity has become a commonly accepted framework employed in current mathematical identity research (Darragh, 2016; Graven & Heyd-Metzuyanim, 2019).

Understanding the evolving definitions and complexities of mathematical identity is further enhanced when presented with the historical context that explains why there has been an increase in mathematical identity research. Analyzing the historical context makes it apparent that today's challenges in articulating and framing this concept are rooted in paradigm shifts over time. From early positivist notions to modern sociocultural constructivist beliefs, the understanding of mathematical identity has undergone a profound transformation. Exploring this historical journey provides insight into how mathematical identity research has evolved in response to changing educational philosophies and societal influences.

**Historical Context**

Mathematical identity research has gained popularity in the last fifteen years, experiencing a significant rise in published articles since 2008 (Darragh, 2016). An analysis of the historical context reveals an ongoing paradigm shift in math education from a positivist perspective, believing that mathematical identities are predetermined, to a constructivist ideology that embraces the sociocultural nature of developing beliefs about the self (Darragh, 2016; Graven & Heyd-Metzuyanim, 2019). It is difficult to pinpoint when academics began investigating the concept of one’s self or identity. Although connections date back to Socrates’
exploration of the concept of virtue circa 400 BCE, it was not until the early 20th century that publications described how individuals develop a sense of identity (Siljanovska & Stojcevska, 2018). Many of the earliest writings on identity development describe individuals as discovering or refining their sense of self through social interactions and behaviors that elicit social approval (Erikson, 1968; Kemph, 1969). These early publications present identity through a positivist lens, suggesting that individuals have a discernible mental or moral personality fixed at birth that is uncovered over time (Erikson, 1968). Erikson (1968) describes how early psychological interpretations of identity formation involve recognizing or discovering oneself rather than an ongoing, dynamic, and complex journey that constructs a person’s beliefs and values.

A Shift Toward Constructivist Ideology

In the 1930s, Lev Vygotsky developed his sociocultural theory of learning, arguing that knowledge and a person’s sense of self are inherently socially constructed endeavors that occur within active, complex, and dynamic social interactions (John-Steiner & Mahn, 1996). Vygotsky’s research is rooted in constructivist ideology. It has led to a rise in identity studies exploring how social and cultural dynamics, such as power, ideology, and social structures, influence how individuals learn and develop a sense of self (John-Steiner & Mahn, 1996). However, positivist views on identity continued to prevail in research. Although embracing a social component, positivist ideology suggests that individuals who feel a sense of belonging and acceptance from society have established a strong identity (Kemph, 1969). In contrast, individuals not accepted or cast out by society have yet to develop a coherent identity (Kemph, 1969). Through a positivist lens, identity is a construct of conformance to societal norms and expectations.
In 1968, a landmark publication by Erikson, “Identity youth and crisis” synthesized identity research through the 20th century and proposed a theoretical framework for understanding identity development. Erikson (1968) suggested that identity construction is a psychosocial endeavor that occurs across an individual's lifespan. His theory emphasizes that individuals constantly resolve identity-related conflicts to achieve a coherent sense of self (Erikson, 1968). Over the next thirty years, Erikson’s ideas grew in popularity. They represent a significant paradigm shift, moving from a positivist view of identity discovery to a constructivist view of identity development (Graven & Heyd-Metzuyanim, 2019). The evolution of the concept of identity is a shift from measuring social or group acceptance to constructing a sense of self from one’s experiences and sociocultural interactions over time.

The Rise of Mathematical Identity Research

As identity research gained popularity, researchers explored the concepts of mathematical identity development within increasingly specific contexts. In 2000, James Paul Gee authored his seminal work, *Identity as an analytic lens for research in education*. This publication presents different ways to study identity in children and argues that the development of students’ identities occurs within the sociocultural dynamics of the classroom (Gee, 2000). Gee (2000) suggests that the sociocultural experiences of children play a significant role in developing a sense of self, processing information, and constructing understanding. Gee’s (2000) publication argues that educators should avoid seeing children in terms of fixed abilities even in the face of societal claims that “people’s biology, chemistry, neurons, and early experiences determine their futures” (p.120). Since Gee’s (2000) publication, educational identity research has experienced a renaissance, with researchers studying the development of student identities, the development of
teacher identities, and the role teachers play in shaping student identities (Darrah, 2016; Graven & Heyd-Metzuyanim, 2019).

The rise in studies specific to mathematical identity is a notable development. In the last decade (since 2010), three times more mathematical identity studies have been published than between 2000-2010 (Darrah, 2016, p.22). The increased popularity of sociocultural constructivist beliefs about how individuals engage in and process math instruction has contributed to the rise in mathematical identity research (Darrah, 2016). In addition, recent advances in brain research have found that the development of positive identities plays a significant role in unlocking the true potential of students (Dweck, 2016).

Current mathematical identity research has explored the formation of mathematical identities within the context of the classroom (Bishop, 2012; Esmonde, 2009; Langer-Osuna, 2011) as well as the development of mathematical identities over time (Boaler & Selling, 2017; Boaler & Staples, 2008; Harper, 2019). Many of these studies and publications recognize the persistent tensions between promoting classroom practices that encourage the development of positive mathematical identities in students and the pervasive positivist mathematical ideology supporting a fixed mathematical ability and intelligence mindset (Boaler & Greeno, 2000; Boaler & Selling, 2017; Langer-Osuna, 2011; NCTM, 2018). In response, a mathematical reform movement has developed to shift the philosophical components of understanding mathematical identities to actionable changes in instructional practices that promote the development of a positive mathematical identity (Boaler & Selling, 2017; NCTM, 2018).

**The Mathematical Reform Movement**

Building upon research from the last thirty years, the mathematical reform movement continues to gain traction and popularity (NCTM, 2018). Characterized by an emphasis on
conceptual understanding, the mathematical reform movement promotes active student learning and engagement, application of mathematical skills across content, and a shift toward problem-solving and reasoning (NCTM, 2018). However, proponents of traditional mathematics instructional practices continue to emphasize rote memorization, mathematical procedural skills, disconnected topics, and ability grouping as effective ways to engage students in math content (Boaler & Greeno, 2000; Boaler & Staples, 2008; NCTM, 2018, Steenbergen-hu et al., 2016). As a result, there is tension between philosophical and pedagogical beliefs about effective math instruction and the actual practice of delivering math content to students.

In 2005, Sfard and Prusak addressed this tension by suggesting that an individual’s identity is reified over time as they process sociocultural experiences and develop a personal narrative. Through experiences, people develop beliefs that influence how they approach, engage, and respond to social settings (Sfard & Prusak, 2005). The work of Sfard and Prusak (2005), combined with Boaler and Greeno (2000) and Gee (2000), provide the foundational argument that classroom experiences, instructional practices, and teachers’ perceptions play a significant role in shaping students’ mathematical identities which, in turn, affect their understandings of mathematical concepts and beliefs about their mathematical abilities.

As a result, mathematics educational philosophy has shifted to promote positive mathematical identities in students as the key to unlocking student potential while deemphasizing traditional practices that focus on procedural computation, speed, and accuracy (Boaler & Staples, 2008; NCTM, 2018). The mathematical reform movement, characterized by its emphasis on conceptual understanding, active learning, and problem-solving, has reshaped perceptions and approaches to fostering mathematical identities in students (NCTM, 2018). Delving deeper into the dynamic nature of learning math, it is evident that shifts in instructional
methods or curriculum choices do not solely shape mathematical identities. Sociocultural contexts within which mathematics is learned, taught, and practiced profoundly influence mathematical identities. Comprehending the sociocultural dimensions of mathematical identities requires more extensive exploration beyond instructional practices or curriculum design changes.

**The Sociocultural Nature of Mathematical Identities**

Individuals’ mathematical identities are a product of their experiences and perceptions (Darragh, 2016; Gee, 2000). According to constructivist ideology, students develop a sense of self through moment-by-moment interactions with peers and teachers. These interactions are social constructs and, therefore, a student’s mathematical identity is a social construct (Bishop, 2012; Esmonde, 2009; Jackson, 2009; Mccarthy & Moje, 2002; Sfard & Prusak, 2005; Turner et al., 2013). McCarthy and Moje (2002) suggest that the philosophical origins of identity as a construct of society are rooted in Vygotsky’s paradigm of the development of self through society. McCarthy and Moje (2002) posit that the social nature of identity complicates how mathematical identities are observed, studied, and explained. How individuals construct their identities may not match how they represent them socially (McCarthy & Moje, 2002).

A person’s identity has much to do with their social interactions. As individuals navigate social situations, their interactions and sociocultural positions shape their beliefs about their abilities (Bishop, 2012). Therefore, researchers must carefully consider how social interactions and discourse provide windows into investigating the sociocultural nature of identity. Building upon our understanding of mathematical identities as social constructs, this section will delve deeper into sociocultural positioning, explore the sociocultural nature of studying mathematical identities, and identify how sociocultural inequities influence the development of positive mathematical identities. The presented research establishes a connection between the
sociocultural nature of learning and the implications for teachers striving to foster positive classroom cultures and communities.

**Sociocultural Positioning and Mathematical Identities**

From a sociocultural perspective, social rules that explicitly and implicitly govern interactions shape mathematical identities rather than mathematical identities taking shape in a vacuum. Within any community, there are power dynamics at play that influence how individuals interact and engage in dialogue and discourse. Wood (2013) describes these interactions as constructed within the social positions that exist within a classroom. In Wood’s (2013) study, the researcher observed and interviewed a teacher and students from a regular education fourth-grade classroom in a typical mid-western city. Wood (2013) spent over thirteen weeks in the classroom to examine how the social dynamics of the classroom influence the development of individual mathematical identities. During this study, Wood (2013) found that interactions within the classroom shape the social positions and identities that individuals develop in the classroom community.

Sociocultural positioning explains how social and cultural factors influence and dictate how individuals navigate the complexity of a school/classroom community and ultimately shape their beliefs about their mathematical abilities (Bishop, 2012; Wood, 2013). Esmonde’s (2009) literature review of research into identity formation within cooperative mathematics classrooms found that community and societal norms significantly influence the quality of cooperative learning experiences and the development of positive mathematical identities. In addition, classrooms where the sociocultural norms are not well-established result in inequity in students’ opportunities to participate in mathematics instruction (Esmonde, 2009).
Sociocultural context also influences how peers position each other within a math class. In a study by Bishop (2012), the researcher found that students commonly reference who is smart or good at math before engaging in mathematical practice. Bishop (2012) conducted an ethnographic analysis of the conversations observed over three weeks among a small group of students in a 7th-grade math classroom in Texas. Bishop’s (2012) research included analyzing the small group interactions within the context of the more extensive classroom and school social structures. Bishop (2012) found that moment-to-moment interactions within the classroom, including between the teacher and students, led to students expressing beliefs about their own and others’ mathematical competency. The study suggests that specific individuals are positioned by their peers and adults to have more significant influence when sharing their thoughts (Bishop, 2012). As a result, they believe they are strong math students (Bishop, 2012). These students overwhelmingly believe that they are good at math, while other students internalize a belief that they are not good at math because their peers devalue their contributions.

Jackson’s (2009) study expands the understanding of the dynamics of the sociocultural influences on learning math. Jackson (2009) observed two African American ten-year-olds over fourteen months in school, home, and community settings. Intending to expose the effects of different sociocultural contexts on the development of individuals’ mathematical understandings, Jackson (2009) found that mathematics instruction cannot occur in a vacuum absent of ever-present social and cultural processes and norms. Jackson (2009) argues that how students construct their understanding of mathematics is rooted in how society influences (or positions) their understanding of themselves.

Additional research into the sociocultural nature of developing math identities confirms that the interactions between students and teachers in the classroom significantly influence how
students engage in and construct mathematical understanding. Langer-Osuna (2011) studied how sociocultural factors and positioning influenced the mathematical identities of two high-achieving 9th-grade students in an algebra class. The researcher found that, although both students had similar strengths in mathematical ability, the interactions among peers and with the teacher positioned the students differently and resulted in the development of two different mathematical identities (Langer-Osuna, 2011). Observing these students on three separate occasions at the start, middle, and end of the school year, Langer-Osuna describes the transition of one of the students who did not experience positive interactions with the teacher and fellow students become less engaged, quiet, and less likely to contribute during collaborative math tasks. In contrast, the other student who received more positive interactions developed into an active group leader and decision-maker who dictated much of the group’s engagement in math tasks (Langer-Osuna, 2011).

**Sociocultural Influences Beyond the Classroom**

Sociocultural positioning gets even more complex when considering the interactions that occur beyond the context of a single classroom. Students are part of a larger school community that includes both formal and informal social interactions. Extracurricular activities and the dynamics of various friend groups influence how students position themselves within the community. Often, students and teachers have to adapt to different sociocultural positions and norms each time they encounter a different social or classroom setting (Horn, 2008). Horn (2008) examined students who entered a California high school with lower math achievement scores and tracked their achievement and experiences as they progressed through high school math programming. Horn found a key result indicating that the combination of learning environments and classroom communities a student experiences influences their long-term mathematical
success. Therefore, students’ identities may change from class to class and year to year as they navigate the ever-changing social dynamics (Horn, 2008).

In a study that focused on constructing mathematical identities and knowledge outside the traditional classroom, Nasir (2002) investigated how individuals’ sociocultural influences change as they move from formal school to informal community settings. Nasir utilized a mixed method design to analyze mathematical learning and identity development of elementary, middle, and high school students and adults who participated in community chess tournaments and basketball games. Nasir found that within informal educational settings, peers commonly position individuals as mentors or mentees to support growth and share knowledge. In contrast, in formal educational settings, peers often view individuals as good or bad at math, stifling collaboration and growth. These studies provide insight into the dynamic and complex nature of the development of identities in individuals. Within the dynamic sociocultural nature of mathematical identity formation, it is no surprise that teachers play a significant role in supporting the development of positive mathematical identities in their students.

Teacher's Role in Promoting Positive Sociocultural Environments

A comprehensive understanding of mathematical identity is incomplete without exploring teachers’ role in positioning students as capable mathematicians. Teachers bring their sociocultural perspectives into the classroom and, as a result, position their students accordingly (Drake et al., 2001; Jackson, 2009). In one study of elementary math classes in an urban school setting with a predominantly People of Color population, interviewed teachers shared the beliefs that historically marginalized students had academic and behavioral deficiencies (Jackson, 2009). Because the staff positioned the students as academically deficient, the teachers used below-grade-level academic resources (Jackson, 2009). They emphasized instructional strategies that
reinforced procedural knowledge over critical thinking and problem-solving (Jackson, 2009). As a result, elementary students continued to fall behind academically and started to develop and articulate negative mathematical identities (Jackson, 2009).

Drake et al. (2001) examined teachers’ beliefs and perspectives during a three-year adoption of a new project-based math curriculum in an elementary school. From the three-year study of 20 teachers, Drake et al. (2001) selected two teachers to participate in a more in-depth qualitative analysis of the teachers’ experiences with the new curriculum implementation. The researchers found that teachers' mathematical experiences as learners influence how they engage with students within their classroom (Drake et al., 2001). Teachers who experience progressive, problem-based math instruction as learners are likelier to promote and elevate all students' mathematical perspectives and contributions (Drake et al., 2001). In contrast, teachers who experienced procedural-based math instruction tend to position students who demonstrate speed and accuracy over other students and expressed more significant discomfort with collaborative problem-based math instruction (Drake et al., 2001).

To promote equitable positioning structures and foster positive mathematical identities within the classroom, educators must be aware of and model appropriate sociocultural interactions with students. Turner et al. (2013) conducted a case study to investigate the effectiveness of an after-school math program designed to support elementary students classified as English learners from a predominantly Latino working-class neighborhood in Texas. Turner et al. (2013) study emphasized the efforts made to provide a culturally supportive environment for the students. The researchers found that teachers who validate student responses and encourage students to explain and reason through their contributions are likelier to position their students as
capable mathematicians (Turner et al., 2013). This finding indicates that teachers play a significant role in establishing positive and supportive sociocultural environments.

In a recent study, Harper (2019) conducted 93 observations in different high school geometry classes for an entire school year. Harper (2019) conducted individual and focus group interviews and, combined with class observations, analyzed how teachers engaged students in math instruction and how individual students responded. Harper (2019) found that individual mathematical identities and social structures greatly influence mathematical authority within the classroom. Therefore, it is necessary for teachers to intentionally plan for the social dynamics of the classroom and build opportunities for students to share mathematical authority (Harper, 2019). Bishop (2012) explains the importance of teachers being aware of and addressing the social nuances during class discourse to ensure equitable positioning for all students. Teachers who position all students as capable mathematicians provide opportunities for students to develop positive mathematical identities and maximize their mathematical abilities.

Examining the sociocultural factors influencing mathematical identities reveals complex interplays between culture, social constructs, and individual experiences. These dynamics create a fertile ground for inequities to manifest in mathematical identities. Analyzing this sociocultural perspective will explore how cultural, racial, and gender dynamics impact students' experiences and shape their mathematical identities. Understanding these influences is critical for educators aiming to foster equitable mathematical learning environments and support the development of positive mathematical identities among all students.

**Sociocultural Inequities Manifesting in Mathematical Identities**

The cultural dynamics that influence classroom social interactions further complicate the situation. Esmonde (2009) finds that culture is directly linked to mathematical identity as they
are both influenced by social constructs and context. The connection between social and cultural influences suggests that the study of mathematical identity falls within the framework of sociocultural constructivism (Sfard & Prusak, 2005). Because of the sociocultural nature of identity studies, the cultural inequities present in society and math classrooms today also serve as barriers to students developing a positive and inclusive mathematical identity.

Rodriguez et al. (2004) conducted studies observing Latino students, and Turner et al. (2013) observed Black students placed in additional learning environments composed of students with similar cultural and racial backgrounds. Both studies found that when historically marginalized students were empowered to contribute and share their perspectives, they developed a stronger positive mathematical identity and increased their participation in learning experiences. Furthermore, Turner et al. found a strong correlation between the cultural relevance of educational experiences and the development of students’ mathematical competence and identities.

Another commonly investigated topic is the role that gender inequities play in math education and the formation of mathematical identities. Darragh (2016) identified twenty-one recently published articles examining the role that gender plays in the experience and formation of individuals’ beliefs about their mathematical abilities (p.23). In one quantitative study of 247 American elementary school students, Cvencek et al. (2011) explored how early gender inequities and stereotypes get communicated and internalized by students. The Cvencek et al. (2011) research surveyed elementary students in implicit and explicit markers to determine if and when gender bias exists and is internalized by students. The researchers found that students as early as second grade identified implicit and explicit gender stereotypes that resulted in boys feeling more confident about their mathematical abilities (Cvencek et al., 2011).
Two additional studies found that boys develop a greater positive belief about their math abilities compared to girls (Solomon, 2007; Upadyaya & Eccles, 2014). In a study of eighteen boys and girls in England, Solomon (2007) interviewed high school students about their experiences in math classrooms to determine how gender affects the development of personal identities. Solomon found that female students had a much lower perception of their mathematical abilities. Even when female students performed well on math assessments, female students expressed doubts about their mathematical competence (Solomon, 2007). Females were less likely to choose career options related to mathematics (Solomon, 2007). Upadyaya and Eccles (2014) conducted a quantitative analysis of school data and survey responses provided in waves over four years in a southwest Michigan elementary school. The sample included 849 kindergarten to third-grade students and their teachers (Upadyaya & Eccles, 2014). Upadyaya and Eccles found that boys had a higher self-confidence in their math abilities than girls and that teachers’ perceptions of their students significantly impacted the students’ beliefs about their mathematical abilities.

Research into the inequitable practices associated with gender identities within math classrooms uncovers systemic bias that continuously places females and historically marginalized groups in negative positions (Belfi et al., 2012; Boaler & Selling, 2017; Boaler & Staples, 2008; Gamoran, 2009; Schofield, 2010). Boaler and Staples (2008) conducted an in-depth case study on three California high schools in which the research team used a mixed methods design conducted over multiple years. The study aimed to explain how applying ability grouping and providing a more collaborative problem-based curriculum affects students' achievement and beliefs about their mathematical abilities (Boaler & Staples, 2008). Boaler and
Staples found that the practice of ability grouping negatively affects females and historically marginalized students.

Understanding the impact of ability grouping on the development of an individual’s mathematical identity provides essential insight into the educational structures that maximize long-term student growth and achievement. Ability grouping students harms students’ ability to develop a participatory self-identity (Solomon, 2017). Boaler (2013) agrees with this assertion and argues that schools that abandon ability grouping practices and move to mixed or heterogeneous grouping will see student achievement and participation (p.147). Further solidifying the importance of establishing a positive self-identity, Belfi et al. (2012) completed a literature review on the effects of class composition on students’ school well-being and academic self-concept. Belfi et al. limited their literature review to studies where they statistically controlled for students' backgrounds. This restriction aimed to ensure that students’ perceptions of their academic self-concept resulted from grouping practices, not background experiences. Belfi et al. concluded that ability grouping harms students’ academic self-concept. Chimielewski et al. (2013) also supported this conclusion by finding that students placed in low-ability groups developed a weak mathematical self-concept. Belfi et al. (2012), Boaler (2013), Chimielewski et al. (2013), and Solomon’s (2007) research provides strong evidence that the practice of ability grouping students is inequitable and affects women and historically marginalized student groups in a way that significantly challenges their ability to foster a positive mathematical identity.

Optimistically, the research conducted by Boaler (2013), Boaler and Selling (2017), and Belfi et al. (2012) provides perspectives on possible solutions for schools striving to address the need to increase student achievement without promoting inequitable sociocultural systems. The research found that developing positive student self-identities in mathematics results in long-
term achievement gains for all students (Boaler, 2013; Boaler & Selling, 2017). These studies suggest that it is difficult to overcome the sociocultural complexities and inequities associated with the development of mathematical identities. However, by carefully considering sociocultural factors, educators can cultivate classroom communities that will support all students’ achievement and growth. A complete analysis of the implications of the sociocultural nature of math education for teachers helps identify the need for teachers to understand how their own beliefs shape and influence their classroom community.

**The Implications of the Sociocultural Nature of Math Education for Teachers**

Armed with the knowledge of how sociocultural interactions influence the construction of students’ mathematical identities, teachers must carefully consider their choice of resources and instructional strategies. Rodriguez et al. (2004) discovered a direct connection between the successful development of positive student identities and intentionally designed and delivered curriculum that highlights and invites cultural connections and unique perspectives into collaborative learning experiences. Solomon (2007) identifies the importance of developing a participatory or active identity to maximize student engagement and achievement. Solomon adds that teaching practices that embed dialogic discourse and collaborative discussions, value unique perspectives, evaluate individual contributions, and encourage creative problem-solving will promote a positive self-identity that results in long-term student growth and high achievement.

In addition, teachers’ perceptions of how students learn mathematics will influence the way in which curricular resources are adapted and presented in the classroom. Drake and Sherin (2006) found a link between teachers’ modifications of curricular resources, their experiences as math learners, and their mathematical identities. Therefore, teachers who experienced strong sociocultural influences in their educational experiences may unintentionally replicate these
norms in their classrooms. Furthermore, to promote equitable, dialogic mathematical discourse among students, teachers must provide opportunities for all students to enter the conversation and learn together. Educators can actively position students as competent mathematicians by providing learning experiences that all students can engage in and make contributions (Empson, 2003). Furthermore, teachers need to cultivate frequent opportunities for students to participate and share ideas (Empson, 2003) while dismantling gender and racial stereotypes that perpetuate sociocultural inequities.

In order to promote the development of positive mathematical identities, teachers must look beyond the curriculum and consider their use of instructional strategies in the classroom. Emphasizing mathematical discourse, conceptual thinking, and sense-making is crucial to establishing positive mathematical identities that lead to connected knowledge (Boaler, 2002; Boaler & Greeno, 2000; Empson, 2003). Esmonde (2009) identified that the quality of group work and student interactions, not quantity, matters most in shaping positive mathematical identities. Teachers should consider group composition and peer social status when engaging students in collaborative work (Esmonde, 2009). Harper’s (2019) study also finds that adding critical mathematical inquiry (CMI) practices into the classroom allows students to assess problems, make sense of the situation, and work collaboratively toward a better understanding. Harper defines critical mathematical inquiry practices as learning experiences that require mathematical reasoning and investigation in which students ask questions, solve problems, and explain ideas. Additionally, by setting structures that encourage shared mathematical authority, teachers promote a more equitable classroom community where all students can develop a positive mathematical identity (Cobb et al., 2009; Harper, 2019).
Once teachers have implemented curriculum and teaching strategies that promote the development of positive mathematical identities, they should focus on fostering a classroom culture that supports mathematical engagement and identity. Empson (2003) suggests that students’ success in a mathematics classroom largely depends upon the teacher’s role in making space and meaning for students’ contributions to class discourse (p.306). Furthermore, Empson (2003) and Wood (2013) warn that students who engage in mathematical discourse with only procedural knowledge or non-mathematical contributions are not growing their mathematical understanding. Therefore, classroom cultures must support opportunities for all students to engage in high-level mathematical dialog with space and time for individual students to grow at their own pace. Nasir’s (2002) study suggests that mentor/mentee relationships observed in the community may be a good model for teacher/student relationships in the classroom. Finally, students will experience struggles throughout their mathematical journeys. When these struggles occur, teachers should challenge the assumption that student struggles are due to a lack of student ability or effort (Horn, 2004). Horn (2004) posits that teachers who provide instructional support while maintaining high expectations can foster a positive mathematical identity that will persist (p. 62).

**Challenges Associated with Studying Mathematical Identity**

Early research into mathematical identities focused on how students construct their long-term sense of mathematical ability. Wood (2013) categorizes these studies as investigations into the mathematical macro-identities of individuals. Studies of mathematical macro-identities focus on the long-term construction of an individual’s identity over time and suggest a more permanent outcome to how students view their mathematical capabilities. Boaler and Greeno (2000) claim that the context in which students engage in mathematical practice influences the long-term
development of their mathematical identity. However, there is a debate between researchers over the factors that most affect the development of positive long-term mathematical identities.

Boaler and Greeno (2000) argue that participation in dialogic, problem-based learning that promotes mathematical discourse between students and teachers fosters a positive mathematical macro-identity. Cobb et al. (2009) suggest that as individuals socially construct macro-identities, they progress toward the desired identity of a student for whom success in mathematics is maximized. Rodriguez et al. (2004) find that students who make culturally relevant connections to learning develop a positive mathematical identity that supports future academic success. Finally, Brown's (1996) study concludes that individuals' unique perspectives of their classroom experiences influence their identity development. Students’ experiences and sense-making construct their mathematical identity over time. Regardless of the cause-and-effect relationships presented in these studies, macro-identity research shares a common theme of students progressing toward a predetermined desired state of positive mathematical identity.

**Tensions Between Micro and Macro Identity Research**

However, Wood (2013) argues that students do not have an inherent pathway that leads to a desired mathematical identity. Instead, Wood’s (2013) research suggests that the micro-level in-the-moment interactions and experiences form individuals’ identities. More recent research on mathematical identities has focused on the dynamic nature of micro-identities as they unfold within the context of student experiences (Bishop, 2012; Harper, 2019; Horn, 2008; Langer-Osuna, 2011; Turner et al., 2013; Wood, 2013). This research suggests that, by studying how mathematical micro-identities develop, researchers receive a more complete understanding of how mathematical macro-identities form. Just like the trailer for a movie, research into macro-identities may provide an overview. However, without experiencing the entire film or studying
the progression of micro-identities, it is impossible to understand the complexities and nuances that complete the story.

The sociocultural nature of mathematical identity research requires the consideration of both short and long-term influences on an individual’s mathematical identity. Radovic et al. (2018) systematically reviewed the literature on mathematics learner identity. Their review provides clarity, suggesting researchers can define the purpose of their study within the context of specific categories that allow for the identification of identities and the manifestation of identities in practice and beliefs (Radovic et al., 2018).

Looking ahead, the field of mathematical identity research holds great potential. Future studies may delve even deeper into micro-identities, exploring the intricate moments of identity formation. Additionally, researchers can continue to investigate the impact of sociocultural factors, classroom environments, and teaching practices on the development of mathematical identities. By embracing the complexities of both micro and macro identities, researchers can contribute to a more comprehensive understanding of mathematical identity, ultimately paving the way for more effective educational practices and policies that promote positive mathematical identities among all learners.

**Defining Mathematical Learning**

Another challenging aspect of studying the effects of mathematical identities on students’ mathematical growth is determining a framework for identifying and measuring how students gain mathematical understanding. When studying how students learn mathematics, researchers have found that student achievement on assessments is an insufficient measure of growth in mathematical knowledge (Boaler, 2002; Boaler & Greeno, 2000; Cobb et al., 2009). Instead, the research suggests that growth in mathematical understanding occurs when students are making
sense of mathematics, engaging in problem-solving, and participating in dialogue and discourse
to construct meaning (Boaler, 2002; Boaler & Greeno, 2000; Empson, 2003).

Boaler (2002) describes insight into how students demonstrate their mathematical understanding. Boaler concludes that students have only gained actual mathematical knowledge if they can apply it in a non-procedural-based application in real-world contexts. Boaler and Greeno (2000) describe two types of mathematical understanding. “Received knowing” (passively being able to apply procedural knowledge within the context of presented problems) is considered a lower depth of knowledge compared to “connected knowing” (being able to apply mathematical understanding in any context when applicable) (Boaler & Greeno, 2000, p. 174). Scholars agree that students who demonstrate connected knowing and engage in mathematical discourse achieve higher mathematical knowledge and growth (Boaler, 2002; Boaler & Greeno, 2000; Empson, 2003).

However, challenges exist within this framework for measuring mathematical growth and understanding. Specifically, not all mathematical discourse or application demonstrates the same level of mathematical competence. Expanding on this idea, Empson (2003) acknowledges the struggles associated with low-achieving students in dialogic-based instructional models. Specifically, Empson (2003) recognizes that low-achieving students’ contributions to classroom or group discussions tend to be minimal and non-mathematical in nature.

Cobb et al. (2009) provide a possible solution to the challenges of studying mathematical understanding within this framework. In a comparative study of two contrasting urban middle school math classes, Cobb et al. (2009) observed eleven 8th-grade students through forty-one recorded observations over eleven weeks. Their research suggests that analyzing the closing of the gap between the student’s current identity and the desired normative mathematical identity is
an effective measure of the student’s mathematical understanding (Cobb et al., 2009). Regardless of the quality of the discourse, engagement, or sense-making, if students progress from their current state to a state of improved beliefs about their mathematical competency and sense-making, they have gained mathematical understanding (Cobb et al., 2009; Empson, 2003).

**Implications for Researchers**

The study of mathematical identity presents several intricate challenges that researchers must navigate to contribute effectively to this evolving field. Moreover, researchers must prepare to embrace the dynamic nature of mathematical identities, acknowledging that these identities are not static constructs but evolve through complex interactions (Wood, 2013). One of the foremost challenges lies in clearly defining and framing the context of their studies. As the sociocultural nature of mathematical identity is multifaceted and context-dependent (Darragh, 2016; Graven & Heyd-Metzuyanim, 2019), researchers must provide a precise definition of mathematical identity and establish a strong theoretical framework that contextualizes their work within the broader landscape of identity research.

**Theoretical Framework**

Research is grounded in an aligned philosophical and methodological approach through a theoretical framework that provides the context or lens through which a researcher investigates a problem (Grant & Osanloo, 2014). This mixed-method explanatory sequential study investigates how elementary math teachers' mathematical identities influence their beliefs about effective mathematical instructional practices and their perception of students’ mathematical skills. Investigating teachers’ mathematical identities is a complex endeavor that requires examination of the construction and manifestation of personal beliefs in educators' practices. Vygotsky’s sociocultural theory of learning and Sfard and Prusak’s (2005) theory of mathematical identity
provide the theoretical framework for this research. The following section will explore the key concepts and principles of Vygotsky’s sociocultural theory of learning and Sfard and Prusak’s theory of mathematical identity. The intersection of these theories will be presented within the context of the study to connect the development of teachers’ identities with their perceived beliefs about students and effective instructional practices.

**Vygotsky’s Sociocultural Theory of Learning**

In the 1920s, Vygotsky constructed his sociocultural theory of learning to explain the interdependence of social and individual processes on constructing knowledge in learners (John-Steiner & Mahn, 1996, p. 191). The sociocultural theory of learning embraces the paradigm that social interactions are at the core of individual development and that individual development is the transformation of social interactions into internalized beliefs and understandings (John-Steiner & Mahn, 1996; Penuel & Wertsch, 1995). According to this theory, learning and development are not solely determined by individual factors but are deeply rooted in the social and cultural contexts in which individuals participate.

Vygotsky’s sociocultural theory identifies the social interactions among learners, cultural tools and signs, and the internalization and construction of knowledge as the fundamental sociocultural tenets through which individuals construct understanding (John-Steiner & Mahn, 1996). Vygotsky argued that individuals construct understanding and develop skills through social interactions with parents, teachers, and peers (John-Steiner & Mahn, 1996). The sociocultural theory of learning emphasizes that culturally constructed tools, such as language and symbols, are how individuals engage in social interactions and play a crucial role in influencing individuals’ internalization of thoughts (Penuel & Wertsch, 1995). Through the transformation process, individuals’ social interactions will become internalized and develop
their understandings, skills, and sense of self (John-Steiner & Mahn, 1996; Penuel & Wertsch, 1995). Vygotsky’s sociocultural theory of learning emphasizes the connection between individuals, their social environment, and the cultural resources contributing to their development.

In the current research, many studies have applied Vygotsky’s sociocultural theory of learning to examine the role social interactions play in shaping and constructing an individual’s sense of self (Boaler & Selling, 2017; Bishop, 2012; Horn, 2008; Langer-Osuna, 2011; Nasir, 2002). Some studies focus on the social interactions and discourse that occur within a classroom (Bishop, 2012; Langer-Osuna, 2011), while others explore the long-term effects that social interactions have on the development of learners’ identities and beliefs (Boaler & Selling, 2017; Horn, 2008; Nasir, 2002). The results of these studies support Vygotsky’s sociocultural theory of learning by finding that social interactions, the language/discourse used, and individual construction of knowledge through transformation are all significantly influenced by the social experiences of individuals both in moment-to-moment experiences and over time. However, sociocultural theory does not explain how an individual's construction of knowledge or sense of self becomes reified into an identity that people believe about themselves. To better understand the impact of sociocultural theory, there is a need to examine the intersection between sociocultural theory and identity.

**Mathematical Identity Theory**

Vygotsky’s sociocultural theory of learning provides a foundation for Sfard and Prusak’s (2005) theory of mathematical identity. Mathematical identity theory explores the formation of individuals’ identities, or sense of self, within the specific context of mathematics education. It also bridges learning and the social context in which it occurs (Graven & Heyd-Metzuyanim,
Sfard and Prusak (2005) define mathematical identity as a “set of reifying, significant, endorsable stories about a person” (p.14). In the most simplistic form, mathematical identities manifest in the statements, I am good at math or I am not good at math, and once established, individuals’ identities influence how they interact and approach mathematical problem-solving (Bishop, 2012; Boaler & Selling, 2017).

Sfard and Prusak (2005) establish their mathematical identity theory based on ideologies about constructing identity, the role of narratives and stories in forming identity, the dynamic nature of identity development, and the intersectionality of social and identity constructs. Sociocultural beliefs that recognize how individuals are influenced by various external experiences, leading to the reification of beliefs, attitudes, and self-perceptions related to mathematics underpin mathematical identity theory (Graven & Heyd-Metzuyanim, 2019). A key component of Sfard and Prusak’s (2005) mathematical identity theory is the significant role that personal narratives, the stories people tell about themselves, play in shaping mathematical identities. Furthermore, intersecting sociocultural factors, such as social power constructs, cultural background, socioeconomic status, gender, and race, impact an individual’s constructed identity (Graven & Heyd-Metzuyanim, 2019; Sfard & Prusak, 2005). Mathematical identity theory suggests that identities are dynamic and can evolve through new experiences, learning opportunities, and interactions (Sfard & Prusak, 2005).

Integration of Sociocultural Theory and Mathematical Identity Theory

Vygotsky’s sociocultural theory of learning provides a broad framework that connects all social interactions and cultural contexts to developing knowledge and a sense of self. Sfard and Prusak build upon this framework to describe how an individual’s sense of self develops into believable, personal stories known as their identity. When specifically applied to mathematics,
this narrative is known as an individual's mathematical identity. Figure 2.1 illustrates the interconnection between Vygotsky’s sociocultural theory of learning and Sfard and Prusak’s mathematical identity theory.

**Figure 2.1**

*Interconnection of Sociocultural Theory and Mathematical Identity Theory.*

The natural integration of sociocultural learning theory and mathematical identity theory forms the theoretical framework for this study. Teaching is inherently a social construct in which the interactions between educators and students provide the context for learning (Graven & Heyd-Metzuyanim, 2019; Sfard & Prusak, 2005). Recent publications utilizing a similar theoretical framework have explored the role that teachers’ mathematical identities play in fostering a positive identity in their students (Aguirre et al., 2013; Cross Francis, 2014; Lutovac & Kaasila, 2017) Additional studies have investigated the development of students’
mathematical identities through social interactions, dialog, and the engagement in mathematical problem-solving (Boaler & Selling, 2017; Bishop, 2012; Horn, 2008; Langer-Osuna, 2011).

**Applying Sociocultural and Identity Theory Frameworks**

This dissertation expands upon previous research by investigating how elementary math teachers' mathematical identities are formed and influence their beliefs about effective mathematical instruction and their perception of students’ mathematical skills. Participants share the social and cultural experiences that influenced the development of their mathematical identities and then project how their mathematical identities influence their instructional choices and beliefs.

Integrating Vygotsky's sociocultural theory with Sfard and Prusak's mathematical identity theory provides a framework for a comprehensive understanding of how social interactions, cultural resources, and personal experiences intersect to shape individuals' identities about mathematics. The theoretical framework implemented in this study constructs a deeper understanding of how teachers’ experiences shape their mathematical identities and, in turn, influence their instructional practices and perceptions of students. This integration allows for a more nuanced exploration of the complex processes underlying the construction of mathematical identities. It provides a foundation for investigating the implications of teachers’ identities on instruction.

In summary, the theoretical framework presented here, which integrates Vygotsky’s sociocultural theory of learning with Sfard and Prusak’s mathematical identity theory, provides a robust foundation for examining the intricate interplay between teachers' mathematical identities, instructional beliefs, and perceptions of students' mathematical skills. This framework places social interactions, cultural contexts, and personal narratives at the center of our understanding of
the construction of mathematical identities and how they, in turn, impact teaching practices. Building upon this theoretical groundwork, the following section delves into the research methodologies supporting our investigation of mathematical identities and their complex dynamics.

**The Research Methodologies that Support the Study of Mathematical Identities**

Mathematical identities are dynamic and develop as a construct rather than an absolute. Given this challenge, research into mathematical identities commonly employs qualitative methodologies rooted in constructivist ideology (Darragh, 2016; Graven & Heyd-Metzuyanim, 2019; Radovic et al., 2018). Sfard and Prusak (2005) claim that students’ identities are narrative and constructed from an individual’s personal stories and the stories told to and about the individual in a social context. Therefore, studying mathematical identities requires interpreting and constructing a common understanding between the researcher and participants.

Brown’s (1996) theoretical phenomenology study dissected individuals’ engagement in math tasks and the development of embodied beliefs about themselves through lived experiences. Brown’s (1996) work suggests that mathematical identity develops through an individual’s sense-making of their perspective, predicted experiences, and actual experiences. Research methodologies that allow researchers to dissect and interpret observed behaviors and individual and social perceptions are essential in understanding how mathematical identities are formed and influence teaching and learning (Brown, 1996).

**Qualitative Research and Mathematical Identities**

Researchers commonly employ qualitative methods, including narrative research, case studies, or interpretive designs, to unpack the complexities of studying mathematical identities (Darragh, 2016; Graven & Heyd-Metzuyanim, 2019). These qualitative studies often collect data
through interviews, observations, autobiographies, and document analysis (Darragh, 2016; Radovic et al., 2018). Commonly, researchers conduct qualitative mathematical identity studies on relatively small numbers of participants, with more than half of recent studies (since 2015) including less than ten participants (Darragh, 2016, p.23)

In Drake et al. (2001) and Drake and Sherin's (2006) studies, narrative research design allowed the researchers to connect past experiences and present constructs of mathematical identity. Drake et al. (2001) included ten elementary teachers from three schools adopting a new math curriculum. In the study, the researchers observed the teachers between ten and fifty times over two school years. Interviews followed each observation to capture the perspectives and narratives of the participating teachers (Drake et al., 2001). As a result, Drake et al. (2001) provided detailed findings that connected short-term experiences with the long-term development of participants’ beliefs about the effectiveness of the new math curriculum. In Drake and Sherin’s (2006) study, the researchers chose two teachers from the Drake et al. (2001) research and had them participate in narrative story interviews. Story interviews are another example of the importance of providing opportunities for participants to explain and provide context to their mathematical identity formation and manifestation.

Although there is a common theme of incorporating qualitative methodology into mathematical identity studies, there is diversity in the specific methods and data collection employed. Horn (2004) used a narrative methodology to provide a more comprehensive interpretation and comparison of the nuanced dynamics that shaped the participants’ mathematical identities over time. Rodriguez et al. (2004) and Empson (2003) utilized case study designs to investigate the development of mathematical identities in specific demographic groups of students. Cobb et al. (2009), Harper (2019), and Langer-Osuna (2011) all employed
interpretive methodologies, analyzing observations, interviews, and video recordings to identify emerging themes and understand the factors influencing the development of students' mathematical identities.

Quantitative Research and Mathematical Identities

Although uncommon, mixed methods research supports mathematical identity researchers using a convergence or explanatory design. One example was Boaler and Staples's (2008) mixed methods case study that included over 700 student participants in three high schools. Boaler and Staples (2008) used quantitative statistical analysis of longitudinal math achievement data to draw broad conclusions between the case schools. The researchers then conducted multiple observations and interviews over three years to examine students’ mathematical experiences related to achievement and identity between the schools. Researchers can use a mixed-methods design to identify generalizable trends or categories and further explain them through qualitative data analysis.

Implications for Research

The research suggests that a qualitative phase must be present for researchers to understand how mathematical identities develop and manifest in educational settings. In Darragh’s (2016) literature review of mathematical identity studies, the sheer volume of qualitative research suggests that the complex concept of identity requires detailed descriptions rather than general findings from larger groups (Darragh, 2016, p.23). The constructivist nature of studying mathematical identities relies on the unique context in which researchers conduct each study. Therefore, there is an ongoing need for additional research to gain a deeper understanding of the dynamic and complex nature of how mathematical identities influence mathematical understanding and growth in unique situations.
A Focus on Teacher’s Mathematical Identities

With the ultimate goal of maximizing students’ growth and achievement, teachers carefully plan and deliver instruction utilizing various pedagogical strategies. Embracing a constructivist epistemology, students construct understanding through complex and ongoing interactions that provide the context by which they can apply and hone new learnings. A constructivist framework provides a clear rationale for teachers' vital role in supporting students as they develop understanding and beliefs about their mathematical abilities. The mathematical reform movement shifts the teacher's role from one who conveys and delivers content to one who facilitates collaborative, problem-based learning in which students strive to make sense of mathematical concepts (Boaler, 2015; Boaler & Staples, 2008; Bray, 2011; Huinker et al., 2020). Research shows that teachers' perceptions and beliefs significantly impact the effectiveness of this movement in their classroom communities (Bray, 2011; Campbell et al., 2014; Hughes et al., 2019; Stipek et al., 2001). The following section examines research exploring the role teachers’ mathematical identity and perceptions of students’ mathematical abilities play in influencing their instructional practices and mathematical self-confidence.

The Influence of Teachers’ Beliefs/Perceptions on Instructional Practice

Educators often assume that there is a connection between what teachers believe or perceive to be true and the instructional practices that teachers use and value in the classroom. As a point of clarification, Campbell et al. (2014) suggest that a teacher’s beliefs/perceptions differ from teacher knowledge in that beliefs/perceptions are not verifiable or based on facts. Using Campbell et al.’s definition, many studies have corroborated this assumption by finding empirical evidence that a connection does exist between an individual’s beliefs about teaching and learning and the influence these presumptions have on teaching practices (Bray, 2011;
Stipek et al. (2001) conducted an extensive mixed-methods study with twenty-one elementary school math teachers for one school year. The researchers had participants complete pre- and post-surveys that included Likert scale questions, collect classroom observations, and conduct interviews. Stipek et al.’s (2001) research found that elementary mathematics teachers who held more traditional beliefs that students learn math from continued procedural practice emphasized instructional strategies emphasizing teacher control, computation speed, and procedural knowledge.

In a similar investigation, Bray (2011) studied elementary math teachers’ beliefs about student errors in math class discussions. Bray (2011) utilized a case study design that included four third-grade teachers from an urban elementary school in southeast America. The researcher used classroom observations to code collected data into thematic beliefs and knowledge about student errors during math instruction (Bray, 2011). Bray (2011) determined a strong relationship exists between teachers' beliefs and how teachers structure discussions and address errors in class. Adding to this understanding, Upadyaya and Eccles's (2014) research found that teachers' beliefs about their content knowledge influence their instructional practices and confidence in delivering math content. In combination, these studies demonstrate that teachers' inherent beliefs significantly influence how mathematics is taught to students.

Two additional studies provide strong examples of the pervasive influence that teachers’ beliefs can have on how instruction is planned and delivered. In a narrative study by Drake and Sherin (2006), teachers adopting an elementary reform-based math curriculum were interviewed to explore how they adapted the design and delivery of the curricular resources. The study found
that teachers commonly adapted the lesson structure and design to match instructional delivery methods that they were more familiar with and believed were effective ways for students to learn mathematics (Drake & Sherin, 2006, p.183). Hodges & Hodge’s (2015) study of pre-service elementary teachers found that student teachers struggled when placed with mentor teachers who utilized teaching strategies that did not align with their experiences or beliefs about how students should learn math. These studies' qualitative research designs provide context for how teachers' prevailing beliefs influence math instruction and the measure of student success.

**Teachers’ Beliefs/Perceptions about the Mathematical Reform Movement**

Given the pervasive connection between teacher beliefs and instructional practices, it is no surprise that schools have struggled to implement the mathematics reform movement with fidelity. In a reformed mathematics classroom, students engage in dialogue, inquiry-based, and collaborative problem-solving. Bray (2011) identifies that the mathematical reform movement is rooted in a constructivist ideology in which students reflect on and reason through personal experiences in the context of their prior understanding to construct knowledge. Stipek et al. (2001) describe a reform mathematics classroom as one where students communicate math ideas and solve problems with others while engaging in mathematical activities confidently and enthusiastically (p.214). Additionally, Hodges and Hodge (2015) describe three themes associated with the reform math movement, including an emphasis on problem-solving, connecting content to students’ lives, and encouraging student dialogue and reasoning (p.107).

Research shows that the challenges associated with adopting the mathematics reform movement are primarily due to the fact that teachers experienced more traditional mathematics instruction when they were students and, therefore, do not believe in a constructivist approach to math education (Boaler & Staples, 2008; Bray, 2011; & Wilkins, 2008). Wilkins (2008)
conducted a study surveying 481 K-5 teachers from rural schools in Southeast America. Wilkin’s (2008) study is unique in that the survey compared teachers’ content knowledge and their beliefs about math instruction. Wilkin’s (2008) study found that primary (K-2) teachers shared more positive attitudes about inquiry-based mathematics practices because of their experiences with young students who naturally construct understanding through experience (Wilkins, 2008, p. 156). However, third through fifth-grade teachers' beliefs about the effectiveness of progressive mathematics instruction decreased, and they were less likely to try inquiry-based instruction (Wilkins, 2008). Bray’s (2011) research identifies an additional challenge with adopting a reform mathematics instructional approach. The study concluded that, even if teachers share beliefs that align with the reform mathematics approach, they do not guarantee that they will implement these instructional strategies (Bray, 2011, p. 7).

In one case study, a school overcame these challenges and adopted a mathematics approach aligned with the reform movement. Boaler and Staples (2008) describe how, through a school-wide initiative, teachers collaborated and developed instructional tasks that promoted inquiry-based learning in math classrooms. Boaler and Staples (2008) observed that teachers, when provided with time to experience problem-based math instruction and collaborate to develop appropriate teaching strategies, were influenced in their beliefs about the effectiveness of problem-based math instruction. Boaler (2015) identifies providing teachers with time to experience inquiry-based mathematics instruction and develop tasks that promote reform mathematics skills as critical components in overcoming established teachers’ preference for or reliance upon traditional math structures. Furthermore, Hughes et al. (2019) find that providing teachers with more training on content knowledge will increase the likelihood that they will implement reform mathematics strategies in their classrooms. Although challenging, these
studies suggest that overcoming established traditional beliefs and identities about how mathematics should be taught is possible.

**The Formation of Teachers’ Identities**

Teachers’ perceptions about students’ mathematical abilities shape instructional practices and affect student achievement. Therefore, exploring the factors contributing to developing these influential beliefs is essential. The research finds that teachers’ beliefs about mathematics instruction are rooted in their early experiences as math students and their perception of their mathematical ability or mathematical self-identity (Bray, 2011; Drake et al., 2001; Hodges & Hodge, 2015; Hughes et al., 2019; & Stipek et al., 2011). In Bray’s (2011) study, teachers who identified as having positive math experiences as students were more likely to mimic the instructional practices that they experienced growing up, while teachers who did not have positive math experiences sought to provide their students with different learning opportunities (Bray, 2011, p. 24). Drake et al. (2001) found that teachers will project their perceptions about math instruction onto their students and place a higher value on students who embrace similar mathematical beliefs.

It is important to distinguish between beliefs rooted in prior experiences and teacher perceptions influenced by personal mathematical identities. Research by Hughes et al. (2019) and Stipek et al. (2001) found that teachers' beliefs about their mathematical abilities, or self-concept, influenced the instructional strategies and student outcomes that the teachers value. Stipek et al. (2001) further identified a link between the mathematical identity of elementary teachers and the development of mathematical identities in students. Teachers who believe they are strong mathematicians value making sense of mathematical challenges and foster a culture where students value effort and collaboration and develop a higher sense of mathematical ability.
(Stipek et al., 2001, p. 216). Interestingly, many educators believe that anxiety over change or job responsibilities will also influence teachers' perceptions about effective math instruction. However, Hughes et al. (2019) found that teacher anxiety does not influence instruction, but rather, it is beliefs rooted in past experiences and mathematical confidence that drive teachers' instructional decisions.

**Inequities in Teachers’ Beliefs**

In addition to prior experiences and mathematical identity, studies conclude that gender and racial inequities significantly influence teachers’ perceptions of students' mathematical abilities (Boaler, 2015; Boaler & Staples, 2008; Copur-Gencturk et al., 2019; Robinson-Cimpian et al., 2014; & Sebastian-Cherng, 2017). Elementary math teachers are biased in that male students have greater mathematical competency (Robinson-Cimpian et al., 2014). Robinson-Cimpian et al.’s (2014) study suggests that teachers perceive girls as less capable than similarly achieving boys unless those girls work harder and behave better than the boys (p. 1275). Boaler and Staples (2008) found that teachers’ perceptions that males are stronger mathematicians than females result in fewer female students enrolled in advanced math courses at the secondary level.

Racial prejudices also infiltrate teacher beliefs. Sebastian-Cherng’s (2017) study found that math teachers have less favorable perceptions of Latino and Black students' academic abilities than White students (p. 176). A study by Copur-Gencturk et al. (2019) found that implicit gender and racial biases presented themselves in the perception of student abilities and the interpretation and grading of student work (p. 36). These studies suggest that non-explicit sociocultural gender and race biases significantly influence teachers’ beliefs and perceptions about math instruction and their students.
The Effects of Teachers’ Perceptions on Students

An analysis of the relationship between teacher beliefs, how teacher perceptions form and the impact teacher beliefs/perceptions have on instruction is only complete by investigating what the research suggests about this phenomenon's effects on students. Studies from Stipek et al. (2001) and Upadyaya and Eccles (2014) both concluded that teachers who held more traditional mathematics beliefs placed a much greater emphasis on student computational skills, algorithmic thinking, and getting the “correct” answer. The result was that students' perceptions of their mathematical abilities became directly associated with their ability to compute mathematical problems efficiently and correctly (Stipek et al., 2001). In addition, Upadyaya and Eccles (2014) found that teachers' perceptions of their students’ abilities predicted the students' effort in learning mathematics (p. 112).

Teachers' intrinsic beliefs about race and gender also affect student achievement and mathematical identity. Sebastian Cherng (2017) quantitatively reviewed the Educational Longitudinal Study from 2002. The Educational Longitudinal Study of 2002 surveyed US high school sophomores and teachers about their perceptions of academic rigor and expectations in high school math and English classes (Sebastian Cherng, 2017). Sebastian Cherng analyzed the data of over 12,000 participants and found that there is strong agreement that teacher perceptions matter for student expectations and achievement, and “perhaps more so for youth of color” (p. 180). Robinson-Cimpian et al.’s (2014) study found that elementary teachers' beliefs that male students are better than female students in mathematics resulted in the development of an achievement gap for female students between kindergarten and second grade (p. 1273). Teachers’ intrinsic socio-cultural beliefs infiltrate classrooms and will continue negatively impacting historically marginalized students.
One of the most significant results of teachers acting on their mathematical beliefs is that they influence the development of their students’ perceptions of their mathematical ability. Copur-Gencturk’s (2019) study found that teachers and the classroom environment communicate messages to students that influence their perceptions of their academic abilities (Copur-Gencturk, 2019, p. 37). Furthermore, students who experienced teachers who had developed more progressive beliefs about math instruction had higher motivation, saw mistakes as opportunities to grow and learn, and had a more positive mathematical identity (Boaler, 2015; Boaler & Staples, 2008; & Stipek et al., 2001). Huinker et al.’s (2020) article suggests that teachers set the tone for establishing a positive mathematical identity in students by believing all students can access and make sense of mathematics. Encouraging this perception is a crucial component of maximizing student growth and achievement.

**A Critical Analysis of Changing Teachers’ Perceptions: A Framework for Success**

To conduct a critical analysis of changing teachers' perceptions and establish a framework for success, it is essential to explore strategies for mitigating the adverse effects of traditional and biased teacher perceptions, given the knowledge of how pervasive and influential these beliefs can be on students' mathematical success. Boaler (2015) suggests that addressing these issues early in a child’s mathematical education effectively fosters lasting positive mathematical identities. Huinker et al. (2020) provide recommendations to address teacher beliefs in elementary math classrooms, including: (a) have teachers experience progressive, problem-based math instruction so that they can appreciate the beauty and usefulness of mathematics; (b) dismantle ability grouping to address the inherent socio-cultural belief that some students are good/bad at math; (c) provide training in mathematical concepts so that teachers have the knowledge to support student sensemaking of mathematical concepts (p. 783).
Adding one additional recommendation, Stipek et al. (2001) found that teachers should empower students with more authority over learning experiences in the classroom as a way to build stronger positive mathematical identities.

In addition to the presented recommendations, Sebastian Cherng’s (2017) and Hodges and Hodge’s (2015) studies suggest that pre-service teaching candidates need to learn about the implicit gender and racial biases that they will bring into the classroom and how they can empower all students with an equitable opportunity to learn mathematics. Finally, Boaler (2015) and Boaler and Staples (2008) suggest that using a problem-based reformed mathematics approach to instruction is essential to engaging our students in mathematical discourse that constructs deep and lasting connections to mathematical concepts.

**The Intersection of Teacher’s Identities with Classroom/Pedagogical Beliefs**

The research draws a clear connection between teachers’ beliefs and the instructional strategies used in the classroom (Stipek et al., 2001). These intrinsic beliefs influence how teachers structure discussions, value understanding, and adapt instructional materials (Bray, 2011 & Drake & Sherin, 2006). Furthermore, these beliefs are pervasive and will cause inner conflict when teachers must utilize instructional strategies that do not align with their experiences or perceptions of how students best learn mathematics (Hodges & Hodge, 2015). Because many teachers have experienced traditional math classes in their education, they often believe that traditional math instructional strategies are the most effective (Boaler & Staples, 2008; Bray, 2011; & Wilkins, 2008). Providing teachers with professional development opportunities to experience inquiry-based math instruction can help overcome this challenge (Boaler, 2015; Boaler & Staples, 2008).
Teachers’ beliefs and perceptions form from past experiences and confidence in their mathematical abilities (Bray, 2011; Drake et al., 2001; Stipek et al., 2001). In addition, because of the sociocultural nature of education, gender, and racial biases influence teachers’ beliefs and instructional practices (Copur-Gencturk et al., 2019; Robinson-Cimpian et al., 2014; Sebastian-Cherng, 2017). Teachers’ perceptions of their students are expressed explicitly in instructional practice and implicitly in how teachers perceive their students’ mathematical abilities.

Teachers’ beliefs have real and significant impacts on their students. An achievement gap develops in early primary students, negatively impacting women and historically marginalized students (Robinson-Cimpian et al., 2014). Furthermore, teachers’ beliefs about their students’ mathematical abilities will also directly impact student achievement and growth (Stipek et al., 2001 & Upadyaya & Eccles, 2014). Additionally, Copur-Gencturk’s (2019) findings illuminate how influential teachers’ beliefs about their students can be in shaping individual students’ mathematical identities.

Although the task is challenging, intentional action can minimize the adverse effects that teacher beliefs may have on students. Embracing a progressive mathematics instructional model that values problem-based learning, active student dialogue, and empowering students to have more authority in the learning process will foster teacher and student beliefs that all students can be mathematicians (Boaler, 2015; Bolar & Staples, 2008; & Huinker et al., 2020). Recognizing and eliminating systems that promote gender and racial inequalities will help promote teacher beliefs that all students should have equitable access to mathematics instruction (Sebastian Cherng, 2017). Finally, empowering and educating our future mathematics teachers on the effect of teacher beliefs on student achievement and the development of mathematical identities is a critical component of addressing future problems (Hodges & Hodge, 2015). By reshaping their
beliefs about themselves and their students, mathematics teachers may one day empower all students to appreciate the beauty and usefulness of mathematics as they persevere in their pursuit of constructing mathematical understanding.

**Tensions Associated with Mathematical Identity Research**

Researching the development and manifestation of an individual’s mathematical identity is riddled with nuanced philosophical tensions. Identity research is not new to education, psychology, sociology, or philosophy. As early as 1902, researchers began to connect the formation of an individual’s sense of self with social constructs (Siljanovska & Stojcevska, 2018). Although there is general agreement that the development of one’s sense of self, or identity, is rooted in sociocultural norms, there is much debate over the exact processes by which individuals develop their identities, how identities change over time, and how individual identities manifest themselves within an educational context (Graven & Heyd-Metzuyanim, 2019). Specific to math instruction, disagreements exist between traditional positivist views and constructivist beliefs regarding the philosophy behind and practice of effective mathematics instruction.

The tensions that exist in the current mathematical reform movement illustrate the struggle between philosophical beliefs and instructional practice. These tensions will be presented within the context of this research to frame the lens through which this study will investigate elementary teachers’ mathematical identities and their perceived beliefs about effective teaching practices.

**Identifying the Tension**

The development and manifestation of an individual’s mathematical identity is a complex and multifaceted endeavor deeply influenced by philosophical tensions (Darragh, 2016; Graven
& Heyd-Metzuyanim, 2019; Langer-Osuna & Esmonde, 2017; Sfard & Prusak’s, 2005). Over the years, identity research has shifted from a positivist view to a constructivist perspective that recognizes sociocultural dynamics in identity formation. The mathematical reform movement supports the shift to a constructivist perspective and places a growing emphasis on the development of positive mathematical identities in students (Boaler & Staples, 2008; NCTM, 2018).

Mathematical identity research has recently gained popularity in educational settings (Darragh, 2016; Graven & Heyd-Metzuyanim, 2019). However, tensions persist between traditional positivist beliefs that prioritize measured student achievement and constructivist ideologies that value the development of positive mathematical identities. Critics of constructivist ideologies point to ambiguous definitions of identity often found in mathematical identity research. Research identifies the importance of providing a clear definition and theoretical framework to ground mathematical identity research (Darragh, 2016; Graven & Heyd-Metzuyanim, 2019; Sfard & Prusak, 2005). To address these tensions, I have clearly defined mathematical identity within the theoretical framework of Vygotsky’s sociocultural theory and Sfard and Prusak’s (2005) mathematical identity theory. However, a more complete explanation of how my research will be framed within this tension provides needed clarity.

**Framing My Research within the Tension**

My research examines the impact of elementary teachers’ self-reported mathematical identities on their instructional practices. To increase my study’s validity, reliability, and trustworthiness, I must address the tensions within existing identity research. Darragh (2016) suggests that providing a clear definition of mathematical identity within the context of the study is an essential element often missing from mathematical identity research. In addition, having a
clear theoretical framework addresses concerns associated with a lack of clarity and coherence (Langer-Osuna & Esmonde, 2017).

My theoretical framework builds upon Vygotsky’s sociocultural theory of learning and Sfard and Prusak’s (2005) mathematical identity theory. Sfard and Prusak’s (2005) definition of identity will ground my research in common understanding, and the chosen theoretical framework provides context for my study. Applying the intersection between sociocultural theory of learning and mathematical identity theory allows for an investigation into how elementary teachers’ mathematical identities form and manifest within the classroom's sociocultural context. Strengthening the validity of my study, Sfard and Prusak’s (2005) definition of identity has been widely cited in recent research (cited in 21% of articles between 2010 and 2014), establishing credibility and coherence within the field (Graven & Heyd-Metzuyanim, 2019, p.362).

In addition, my research bridges the philosophical theory of mathematical identity with mathematical instructional practice. To address the identified gap in research (Graven & Heyd-Metzuyanim, 2019), my study will connect teachers’ mathematical identities with their preferred instructional practices and beliefs about students. This connection between the philosophy of math identity and the practice of teaching mathematics gives my study real-life implications for the classroom. My research may help elementary math teachers recognize instructional practices that foster positive mathematical identities in their students while supporting achievement and growth.

**Summary**

This literature review, through the lens of Sfard and Prusak (2005), defines a student's mathematical identity as the solidification of an individual's perception of mathematical ability
through individual and collective stories influenced by personal interpretation as well as social constructs in the pursuit of a more concrete understanding of who I am as a mathematician. Brown (1996) and Sfard and Prusak (2005) find that mathematical identities are a construct of lived and perceived experiences, and researchers have employed constructivist methodologies to deconstruct and make sense of how mathematical identities shape and influence math education.

The historical context of mathematical identity research sheds light on its evolution from a positivist perspective of predetermined identities to a constructivist ideology that recognizes the sociocultural dimensions of identity formation (Graven & Heyd-Metzuyanim, 2019). The historical journey of identity research underscores the transition from fixed notions of identity to a more dynamic and complex understanding. Moreover, the tension between the mathematical reform movement’s focus on conceptual understanding and traditional instructional practices highlights the ongoing challenges in shaping students' mathematical identities. Understanding the sociocultural dimensions of mathematical identities will require a deeper exploration beyond curriculum changes, emphasizing the importance of the broader educational context in shaping these identities.

Because the origins of identity research are rooted in Vygotsky’s concept of developing self through society, studies into mathematical identity are commonly presented within a sociocultural framework (McCarthy & Moje, 2002; Sfard & Prusak, 2005). Given the sociocultural nature of identity studies, researchers have identified many influences on the development of mathematical identities. Furthermore, sociocultural dynamics provide insight into how cultural inequities and established teacher perceptions influence students’ development of their mathematical identities. With this understanding, teachers are responsible for diligently analyzing and managing the social interactions within the classroom and actively empowering all
students’ voices to minimize inequitable positioning constructs (Bishop, 2012; Harper, 2019; Turner et al., 2013). In response, Vygotsky's sociocultural theory of learning, intersected with Sfard and Prusak's mathematical identity theory, provides a theoretical framework emphasizing the significance of social interactions, cultural contexts, and personal narratives in shaping these identities and their influence on teaching practices.

This chapter sheds light on the critical role of teachers' mathematical identities and beliefs in shaping instructional practices and, subsequently, students' mathematical experiences and outcomes. Teachers' beliefs, deeply rooted in their own educational experiences and self-perceptions, significantly influence the strategies they employ in the classroom. Traditional beliefs favor conventional teaching methods, while reform-oriented beliefs align with more student-centered, problem-based approaches.

Moreover, societal biases related to gender and race infiltrate teacher perceptions, impacting students' opportunities and experiences (Robinson-Cimpian et al., 2014; Sebastian Cherng, 2017). These beliefs and perceptions have tangible effects, contributing to achievement gaps and influencing students' mathematical identities. A multifaceted approach is essential to address these challenges, including professional development, a shift toward progressive mathematics instruction, recognition and elimination of systemic biases, and robust pre-service teacher education. By reshaping teachers' identities and beliefs, we can foster a more equitable and empowering mathematical learning environment for all students, maximizing their growth and achievement.

Fostering students’ positive mathematical identities is not an easy task for teachers. Wood (2013) says, “... small shifts in context can create or undermine moments of learning. As a result, the work of teaching seems both impossible and quite empowering” (p. 805). Teachers are
like conductors of an orchestra. The conductor sets the stage and picks the music. Independently, each instrument produces a sound that is sometimes beautiful and complex. However, something magical happens when all the instruments combine, taking turns sharing the melody and producing a whole that is so much more than any one instrument could produce independently. Standing at the podium, the conductor does not play the music but guides and positions the orchestra to work in harmony, producing a masterful composition that leaves a lasting impression. Teachers are the conductors of the sociocultural context of their classroom, and the mathematical discourse is the symphony that produces lasting positive mathematical identities.
Chapter 3 - Methodology

This research examines how elementary teachers’ mathematical identities influence their perception of effective math instruction and explores teachers’ perceptions of the importance of supporting the development of a positive mathematical identity in their classroom. This study employed an explanatory sequential mixed-methods design to investigate how participants' mathematical identities evolve and shape their beliefs about teaching math and the mathematical abilities of their students. In the initial phase, the study utilized a Qualtrics survey to determine the characteristics of participants' mathematical identities. In the study's second phase, participants identified with different mathematical identity characteristics participated in semi-structured interviews. These interviews added context and details to explain the mathematical identities identified in the initial survey. This chapter describes the methodological design of the study, presents information about the participants and study setting, reviews the instruments and data analysis techniques, and presents limitations and considerations associated with the research.

Explanatory Sequential Mixed Methods Design

This study employed a mixed-methods explanatory sequential design completed in two phases. A mixed-methods study is appropriate because of the complexity that exists when conducting educational research (Ponce & Pagan-Maldonado, 2015). An explanatory sequential design uses qualitative data to explain and add detail to initial quantitative results (Creswell & Plano-Clark, 2017). In this study, I collected quantitative data to identify participants’ mathematical identities. Then, I obtained qualitative data to explain the manifestation of participants’ identities within the sociocultural context of the classroom. Mathematical identity research recognizes the challenges associated with studying individuals’ dynamic perceptions
and beliefs (Darragh, 2016), and as a result, using a mixed-methods design is appropriate to develop a nuanced and comprehensive understanding of the problem (Plano Clark, 2019).

In addition, Creswell and Plano-Clark (2017) state that an explanatory sequential design is well-suited for researchers interested in forming groups based on quantitative results and following up with qualitative data collection to explain group characteristics. The quantitative phase of this study provided a broad understanding of the samples’ perspectives, while the qualitative phase explored these findings in greater depth and added individual viewpoints (Creswell & Plano-Clark, 2017). Through the combination of quantitative and qualitative phases, mixed-methods studies are well suited to capture the nature of complex research problems (Ponce & Pagan-Maldonado, 2015). The combined use of quantitative and qualitative data collection addresses individual concerns about the failure of quantitative data to uncover important details and context and the difficulty in generalizing qualitative data to a larger population (Creswell & Plano-Clark, 2017).

An explanatory sequential design occurs in two distinct phases, with an initial quantitative phase followed by a qualitative phase (Creswell & Plano-Clark, 2017; Ponce & Pagan-Maldonado, 2015). The initial quantitative phase includes the collection and analysis of quantitative data. Often, the data collected in the quantitative phase measures characteristics or attributes associated with the problem (Ponce & Pagan-Maldonado, 2015). I used quantitative data to determine the characteristics of participants’ mathematical identities and compare that data to collected demographic information. The quantitative data was also used to collect participants’ beliefs about preferred instructional practices and beliefs about the importance of math instruction and fostering a positive mathematical identity in their students.
In contrast, the qualitative phase of an explanatory sequential mixed-methods design includes collecting and analyzing qualitative data to expand and explain characteristics or attributes determined from phase one (Creswell & Plano-Clark, 2017; Ponce & Pagan-Maldonado, 2015). Data analysis of the initial quantitative phase identified participants’ mathematical identities based on responses to survey questions. I then grouped participants into three profile categories representing a positive mathematical identity, a negative mathematical identity, and a group reporting characteristics of both. I interviewed two representative participants from each profile group and coded the transcripts, providing qualitative data. The qualitative data helped explain the development and manifestation of the participants’ mathematical identities.

This study emphasizes the qualitative phase and would be considered a quant → QUAL design. Creswell and Plano-Clark (2017) explain that researchers who emphasize the qualitative phase in mixed-methods research aim to explain complicated quantitative results while allowing flexibility and responsiveness. Pagan-Maldonado (2015) explains that combining quantitative and qualitative methods is an effective way to intentionally uncover a more complete understanding of the research questions. I chose to emphasize the qualitative phase in this study because the purpose of the research demands a more nuanced understanding of the complex nature of self-reported mathematical identity development and manifestation in the classroom. Figure 3.1 represents a diagram of the study’s explanatory sequential design.
Participants were Pennsylvania-certified mathematics teachers in first through fifth grade. Kindergarten was excluded because of the inconsistency in kindergarten programming (for example, half-day vs full-day) throughout the Commonwealth of Pennsylvania. Furthermore, the study excluded substitute and first-year teachers because of inconsistencies with job requirements and inexperience with professional responsibilities. The inclusion and exclusion criteria aim to decrease the influence of inconsistent educational systems and structures on forming and manifesting the participants’ mathematical identities.

Inclusion Criteria

- elementary 1st - 5th-grade current teachers of mathematics
- certified elementary PA educator
- teachers who hold a full-time contracted position within a public school district
- special education teachers who teach a direct instruction math class

Exclusion Criteria

- substitute teachers
- teachers who currently teach a mixed schedule that includes students in 6-12th grade
- teachers who have an extended absence during the current school year require a long-term substitute
- teachers with less than one year of experience teaching mathematics

**Participants Included in the Quantitative Data Collection**

The population of this study includes elementary teachers from eight public school districts throughout southeastern Pennsylvania. Three participating districts are located in towns, while the other five are in suburban areas. School districts in this area of Pennsylvania serve communities with diverse characteristics. Included in this study were districts located in both high and low socioeconomic areas and districts that provide English language services to more than 45% of their student population (PA Department of Education, 2022). The districts included in this study are generally similar in geographical size, number of schools, and total student enrollment, ranging from 3,100 to 5,000 students per district (PA Department of Education, 2022).

For each participating district, the Superintendent of Schools or other district-designated administrator sent a solicitation email to elementary teaching staff within the district. Each district’s designee supported the communication and distribution of the initial survey and a
follow-up invitation to participate in the study. An estimated 550 teachers received the initial solicitation email for participation. There was a three-week period between the distribution of the initial solicitation and the final communication soliciting participation in the study. The survey was open for a total of five weeks. Seventy total participants provided consent and completed the survey in Qualtrics. I completed an initial data cleaning to remove survey responses that were not 100% complete (n=8) and did not meet the inclusion criteria (n=14). As a result, 48 valid responses, representing 8.7% of the population, were included in phase one of the study. Table 3.1 provides the demographic information for the 48 participants in phase 1 of the study. Appendix A includes the complete demographics for the participants in phase 1 of the study.

**Participants Included in the Qualitative Data Collection**

To identify participants for phase two of the study, I analyzed the survey data to create a Likert scale data set. A Likert scale data set comprises four or more Likert-type survey items combined into a single composite score (Boone & Boone, 2012). Combining specific survey items, I determined a composite score representing each participant's mathematical identity value. I then grouped participants into one of three groups representing a low, high, and average composite mathematical identity. Two individuals were randomly selected from each group to participate in follow-up interviews.

The six participants were teachers from five different districts and six different schools. The participants ranged in age from early 20s to late 50s and represented teachers who work with or have worked with students in first through fifth grade.
Table 3.1

*Participants’ Demographics from Phase 1*

<table>
<thead>
<tr>
<th>Demographic Characteristics</th>
<th>n Count</th>
<th>% of Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>3</td>
<td>6.3%</td>
</tr>
<tr>
<td>Female</td>
<td>44</td>
<td>91.7%</td>
</tr>
<tr>
<td>Prefer not to say</td>
<td>1</td>
<td>2.1%</td>
</tr>
<tr>
<td><strong>Level of Education</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Undergraduate Degree</td>
<td>5</td>
<td>10.4%</td>
</tr>
<tr>
<td>Master’s Degree</td>
<td>43</td>
<td>89.6%</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20-25</td>
<td>1</td>
<td>2.1%</td>
</tr>
<tr>
<td>26-30</td>
<td>9</td>
<td>18.8%</td>
</tr>
<tr>
<td>31-35</td>
<td>6</td>
<td>12.5%</td>
</tr>
<tr>
<td>36-40</td>
<td>4</td>
<td>8.3%</td>
</tr>
<tr>
<td>41-45</td>
<td>8</td>
<td>16.7%</td>
</tr>
<tr>
<td>46-50</td>
<td>6</td>
<td>12.5%</td>
</tr>
<tr>
<td>51-55</td>
<td>10</td>
<td>20.8%</td>
</tr>
<tr>
<td>56-60</td>
<td>3</td>
<td>6.3%</td>
</tr>
<tr>
<td>66 and up</td>
<td>1</td>
<td>2.1%</td>
</tr>
<tr>
<td><strong>Years of Teaching Experience</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-5 Years</td>
<td>8</td>
<td>16.7%</td>
</tr>
<tr>
<td>6-10 Years</td>
<td>11</td>
<td>22.9%</td>
</tr>
<tr>
<td>11-15 Years</td>
<td>5</td>
<td>10.4%</td>
</tr>
<tr>
<td>16-20 Years</td>
<td>8</td>
<td>16.7%</td>
</tr>
<tr>
<td>21-25 Years</td>
<td>6</td>
<td>12.5%</td>
</tr>
<tr>
<td>26-30 Years</td>
<td>8</td>
<td>16.7%</td>
</tr>
<tr>
<td>30+ Years</td>
<td>2</td>
<td>4.2%</td>
</tr>
</tbody>
</table>

*Note:* N count = 48 for each condition. All data is self-reported from the initial survey.
The participants came with varying professional experience; two were in their first five years of teaching, and two had more than 25 years of experience. Table 3.2 includes the demographic data for the participants included in the phase 2 interviews.

Table 3.2

*Participants’ Demographics from Phase 2*

<table>
<thead>
<tr>
<th>Participant #:</th>
<th>Gender</th>
<th>Education Level</th>
<th>Age Range</th>
<th>Teaching Experience in Years</th>
<th>Grade Levels Taught</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Female</td>
<td>Master's Degree</td>
<td>56-60</td>
<td>31+</td>
<td>1st, 2nd, 3rd, 4th</td>
</tr>
<tr>
<td>8</td>
<td>Female</td>
<td>Undergraduate Degree</td>
<td>26-30</td>
<td>1-5</td>
<td>2nd</td>
</tr>
<tr>
<td>9</td>
<td>Female</td>
<td>Master's Degree</td>
<td>46-50</td>
<td>26-30</td>
<td>2nd</td>
</tr>
<tr>
<td>18</td>
<td>Female</td>
<td>Master's Degree</td>
<td>51-55</td>
<td>31+</td>
<td>4th</td>
</tr>
<tr>
<td>31</td>
<td>Female</td>
<td>Master's Degree</td>
<td>26-30</td>
<td>1-5</td>
<td>3rd</td>
</tr>
<tr>
<td>39</td>
<td>Female</td>
<td>Master's Degree</td>
<td>26-30</td>
<td>6-10</td>
<td>3rd, 4th, 5th</td>
</tr>
</tbody>
</table>

*Note:* All data shown was self-reported from the initial survey

**Study Setting**

I contacted fifteen suburban public-school districts in southeastern Pennsylvania to participate in the study. Eight of the fifteen districts provided approval to conduct research. The eight participating districts have student populations representing diverse student demographics, including districts that have more than 45% of their students identified as economically disadvantaged (n=2) and more than 10% of their students receiving English learner support (n=2) (PA Department of Education, 2022). Three participating districts consistently perform in the top
15% of all Pennsylvania schools in math and English language arts as measured by the Pennsylvania System of School Assessment and Keystone exams (PA Department of Education, 2022). Included in this study were twenty-three schools from these eight districts. These schools serve elementary students in kindergarten to 5th-grade buildings (n=12), kindergarten to 2nd-grade buildings (n=2), kindergarten to 4th-grade buildings (n=4), 1st to 5th-grade buildings (n=3), and 3rd to 5th-grade buildings (n=2). Table 3.3 includes general demographic information about the participating districts.

Table 3.3

Demographics of Participating Districts

<table>
<thead>
<tr>
<th>District #</th>
<th>Student Population Size (Rounded)</th>
<th># of Schools Included in the Study</th>
<th>District Size (Square Miles)</th>
<th>% Economically Disadvantaged (Rounded)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3050</td>
<td>4</td>
<td>11</td>
<td>60</td>
</tr>
<tr>
<td>2</td>
<td>3900</td>
<td>3</td>
<td>34</td>
<td>45</td>
</tr>
<tr>
<td>3</td>
<td>4500</td>
<td>3</td>
<td>21</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>3800</td>
<td>4</td>
<td>21</td>
<td>24</td>
</tr>
<tr>
<td>5</td>
<td>3300</td>
<td>4</td>
<td>8</td>
<td>39</td>
</tr>
<tr>
<td>6</td>
<td>3565</td>
<td>3</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>7</td>
<td>5000</td>
<td>2</td>
<td>60</td>
<td>31</td>
</tr>
<tr>
<td>8</td>
<td>4150</td>
<td>4</td>
<td>30</td>
<td>16</td>
</tr>
</tbody>
</table>

*Note:* All data taken from PA Department of Education (2022).

Setting for Data Collection

Participants had the option to complete the questionnaire at their discretion. The survey was open for five weeks, with a second solicitation communication sent out three weeks after the initial solicitation email. The survey took an estimated 15 minutes to complete. Following the
phase one quantitative analysis, six participants completed semi-structured interviews through
Zoom. The interviews were conducted 5 to 7 weeks after collecting the initial survey data. The
delay between the initial survey data collection and interviews was due to the winter break
falling during the period between the two phases. The participants scheduled their interviews for
a time that they preferred. The interviews took about 20 minutes each, and the participants
expressed they were comfortable keeping their cameras on during the interview process.

**Instrumentation**

This study utilizes a survey design during the quantitative phase and a semi-structured
interview design for the qualitative phase. Op't Eynde and De Corte (2003) suggest that studies
using a survey design effectively analyze trends, attitudes, or opinions about mathematical
identity and are a practical tool for gathering data from a large population. Merriam and Tisdell
(2016) recognize that interviews are a commonly used qualitative research data collection
method and can add essential details in a mixed-method design.

**Survey Design**

Phase one of the study used a cross-sectional survey design focusing on an explanatory
relationship between teachers’ self-reported mathematical identities and their perception of
effective math instruction. A cross-sectional survey design provides an opportunity to evaluate
the attitudes and practices of elementary math teachers and allows for explanatory analysis
(Creswell & Guetterman, 2019). I created the survey using Qualtrics with West Chester
University of Pennsylvania licensing. The survey comprises 34 questions in three blocks:
inclusion criteria, demographics, and three sections utilizing a Likert interval/ratio scale.
Appendix B includes a copy of the survey used for this study.
The survey presented questions about personal mathematical identities, beliefs about students, and opinions on effective mathematical instructional practices. I organized these questions into three sections designed to elicit feedback on aspects that identify self-reported mathematical identity. The questions contained statements that participants evaluated on a 5 point Likert scale reflecting values from strongly disagree to strongly agree. I independently constructed the survey for this study. However, my survey follows a format and structure similar to a validated survey by Op’t Eynde and De Corte (2003). In addition, my survey uses similar question stems as items validated by Op’t Eynde and De Corte (2003) that I used to determine mathematical beliefs and identity.

Specifically, Op’t Eynde and De Corte’s (2003) study evaluated a 58-item Likert-scale questionnaire exploring four aspects of mathematical-related beliefs. Employing a principal component analysis, Op’t Eynde and De Corte (2003) computed a Cronbach’s alpha coefficient for each item on their questionnaire. Table 3.4 includes the validated statements from Op’t Eynde and De Corte’s (2002) work and the related survey items I used for this study. These statements relate to individuals’ beliefs about the significance of mathematics and personal mathematical competence.

For this study, the survey’s first section of Likert questions explores teachers’ current mathematical identity. Three of the statements, I enjoyed math class in school, I believe that my elementary math education was effective, and I was a good math student in elementary school, provide insight into participants' prior mathematical identities. The remaining statements relate to participants’ current mathematical identities. I designed the second section of items to explore participants’ beliefs about their current students’ mathematical abilities. Finally, the last section explores participants’ beliefs about effective instructional practices in elementary math classes.
Participants identify which instructional practices they prefer and perceive to be most effective in supporting student construction of mathematical knowledge. Participants also shared which instructional practices they believe are ineffective at supporting students’ academic growth.

Table 3.4

Likert-scale Items Taken or Adapted from Op’t Eynde and De Corte (2003)

<table>
<thead>
<tr>
<th>Validated Likert-scale Items</th>
<th>Related Survey Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>I can understand even the most difficult material presented in a mathematics course.</td>
<td>12.10. I can understand even the most difficult mathematical concepts.</td>
</tr>
<tr>
<td>I like doing mathematics.</td>
<td>12.1. I enjoyed math class when I was in school.</td>
</tr>
<tr>
<td>I'm very interested in mathematics.</td>
<td>12.11. I am interested in mathematics.</td>
</tr>
<tr>
<td>I can understand the course material in mathematics.</td>
<td>12.10. I can understand even the most difficult mathematical concepts.</td>
</tr>
<tr>
<td>Mathematics enables men to better understand the world he lives in.</td>
<td>13.5. I believe that the concepts people learn in math class are vital to their success in life.</td>
</tr>
<tr>
<td>Mathematics is used by a lot of people in their daily life.</td>
<td>12.3 I believe that math is useful in my daily life.</td>
</tr>
</tbody>
</table>

Note: The validated Likert-scale items are from Op’t Eynde and De Corte (2003).

To increase the survey’s reliability, four current teachers reviewed the survey items and provided input on clarity and question structure. After receiving feedback, I made minor changes to remove professional jargon and correct grammatical errors. For example, I added fill-in-the-blank options in the demographic section for participants to clarify if they selected other for any question. In addition, I edited the beginning of all Likert-scale questions to start with I statements.
to help solidify that my survey is asking for participants' perceptions of the items. Two additional individuals tested the survey by completing it on mobile devices and computers to check for compatibility and accessibility.

**Interview and Interview Protocol**

The qualitative phase of the study consisted of semi-structured interviews with individuals representing different mathematical identity profiles identified from the quantitative data analysis. Interviews allow for detailed descriptions and context to explain the emergence of specific profile groups (Creswell & Plano-Clark, 2017). The interviews employed a semi-structured protocol. I chose a semi-structured protocol because it allowed space for me to engage the participants in more profound and richer conversations. Each participant was asked the following interview questions:

- Think back to when you were an elementary student in math class, did you like learning math? Why or why not?
- As a student, did you think you were good at math? How about now as a teacher?
- Describe some teaching strategies you remember your elementary teaches using in math class. Did you think they were effective?
- How did your experiences with math as a student compare to how you teach math as an educator?
- How has your mathematical identity evolved over time? What were some key moments that shaped your identity?
- How do you provide feedback to your students? How does this compare to how you received feedback as a student?
- What teaching strategies do you believe are most effective in your classroom?
Would you prefer to be a student in today’s math class or repeat the experience you had as a student growing up? Why?

Marshall & Rossman (2016) suggest that follow-up questions during semi-structured interviews are critical in understanding the context that may explain or add understanding to the identified phenomenon (p.150). Appendix C includes a copy of the semi-structured interview protocol and questions.

The designed protocol reiterates the purpose of the study to participants and provides the main questions utilized during the interviews. To increase the reliability of the interview data, member checking occurred in two ways. During the interviews, I synthesized and repeated the main ideas from the participants' responses. I allowed the participants to correct or add to my understandings and interpretations (Merriam & Tisdell, 2016). In addition, after I transcribed the interviews, I sent copies of the transcripts to participants so they could add additional comments and clarifications as needed.

**Threats to Validity and Reliability**

According to Dellinger & Leech (2007), potential threats to validity and reliability in mixed methods research designs include challenges to researchers' abilities to draw accurate and significant conclusions. Specifically, failing to identify significant quantitative results to explain in the qualitative phase is a common threat to validity (Creswell & Plano Clark, 2017). Creswell and Plano Clark (2017) emphasize that researchers must connect the initial quantitative results with the qualitative data to establish valid and reliable findings (p.251). As a result, internal and external threats to validity and reliability emerge from the failure to gather sufficient data and through inaccurate data analysis (Dellinger & Leech, 2007). This section will identify specific threats to validity and reliability and present potential researcher bias related to this study.
**Internal Validity**

Internal validity refers to the researcher’s ability to draw correct inferences, or cause-and-effect relationships, between investigated variables (Cresswell & Guetterman, 2019). Internal validity can be thought of as how much alignment exists between the data collected and the research problem (Ponce & Pagan-Maldonado, 2015). I have identified three threats to internal validity, including researcher ability, history, and maturation. Researchers must accurately interpret and analyze the quantitative data and make direct connections to collected qualitative data (Creswell & Plano Clark, 2017; Dellinger & Leech, 2007). Furthermore, Creswell and Plano Clark (2017) suggest that researcher capacity and knowledge are a common threat to mixed-methods research because the researcher must be proficient in quantitative and qualitative analysis.

Cresswell and Guetterman (2019) identify history and maturation as two threats to internal validity in any study where time passes between the beginning and end of the study. History bias refers to the phenomenon in which participants may have new experiences influencing their beliefs between taking the initial survey and participating in the follow-up interviews. Maturation refers to the evolution of participants’ perspectives over time or as a result of participating in the research (Cresswell & Guetterman, 2019).

This explanatory sequential research design took six weeks to analyze the initial survey results, identify profile groups, and schedule follow-up interviews. Given the dynamic nature of mathematical identity and its relationship to experiences, participants' perceptions may have changed between the completion of the survey and participation in the interviews. However, this threat is minimal because most interview questions asked participants to refer to their past as students rather than reflect on current teaching practices or recent learning experiences. In
addition, one of the questions asked participants to share key moments that helped shape their mathematical identities. No participants shared an event that occurred between the survey and the interview.

**External Validity**

External validity refers to the generalizability of the results of a study to other groups or situations (Cresswell & Guetterman, 2019; Ponce & Pagan-Maldonado, 2015). Three identified threats to external validity for this study include volunteer bias, interaction of selection and treatment, and interaction of history and treatment.

The participants in this study were volunteers and did not receive any compensation for participation. Volunteer bias refers to the threat that the characteristics of the participants may not represent the characteristics or opinions of the larger population. Participants have different reasons for participating in research, which may influence their responses. The interaction of selection and participation threat to validity is related to volunteer bias. This validity threat refers to the failure to randomly select participants that accurately represent the larger population (Cresswell & Guetterman, 2019). This threat is particularly applicable during the qualitative research phase of this study.

To address this concern, I analyzed the initial survey results for a normal distribution. A normal distribution of data increases the likelihood that the study’s sample is representative of the larger population (Cresswell & Guetterman, 2019). I determined that a normal distribution existed for participants’ mathematical identity values and then used one standard deviation from the mean to create my three profile groups. I listed all participants willing to participate in interviews for each identified profile group. There were six teachers in the high math identity group, four in the low group, and fourteen in the middle group. I then identified four middle-
group participants with mathematical identity scores on or near the calculated mean. I used Alexa to select a random number to identify two members of each group who I invited to participate in the interviews.

The interaction of history and treatment bias is common when studying historical experiences. Cresswell and Guetterman (2019) explain that when researchers explore how the past influences the present, they must be careful not to draw conclusions that predict the future. In this study, participants self-report their beliefs and opinions and provide insight into their formation through past experiences. As a result, I must be careful not to draw conclusions that are not directly observed or related to the self-reported teacher perspectives.

**Generalizability**

Creswell and Guetterman (2019) acknowledge that with all survey research, one major limitation is the accuracy of the representation of the participants compared to the population. Dellinger and Leech (2007) suggest that the degree to which a study can produce generalizable findings is one way to assess the validity of the mixed methods study. In this study, to achieve generalizability, I must have enough participants in phase one to represent the larger population accurately. Kwak and Kim (2017) suggest that a sample size of 30 is adequate for generalizability to a larger population.

With forty-eight valid results from the survey, I received enough participants to make generalizations to the larger population (Kwak & Kim, 2017). The normal distribution of the survey results and the computation of a Likert-scale composite score further support this claim. In addition, the qualitative phase of the study provides specific context to understand the generalization of the findings. Finally, an accurate description of the participants’ population is included in the participants and setting section to frame the generalizability.
Reliability

Merriam and Tisdell (2016) suggest that, traditionally, reliability “refers to the extent to which research findings can be replicated” (p. 250). However, in social sciences, the specific context in which research is conducted can be difficult to control and replicate. Therefore, reliability in qualitative research is defined as how well “the results of the study are consistent with the data collected” (Merriam & Tisdell, 2016, p. 251). When independent analysis of the data results in similar findings framed within the study context, the researcher achieves a higher level of reliability (Merriam & Tisdell, 2016). Furthermore, the study’s reliability is dependent upon the credibility of the data analysis procedures and interpretation (Dellinger & Leech, 2007).

There is a risk to the reliability of my data if the sample does not accurately represent the population. To address this, I carefully selected the inclusion criteria to identify the specific population of elementary math teachers in southeast Pennsylvania who would be eligible to participate in the study. In addition, I distributed the initial quantitative phase survey to over 600 teachers working in 23 schools throughout 8 districts. Casting a large net increases the likelihood that participants are a representative sample of the larger population. Statistical analysis of the initial quantitative data helps draw conclusions that show statistically significant relationships, limiting the need for subjective interpretation. Furthermore, I distributed the survey electronically, ensuring the continuity of experiences for all participants. I sent solicitation communications through district representatives to ensure the same communications went out to all possible participants.

One of the most significant threats to reliability is the coding process when analyzing interview transcripts (Saldana, 2015). To help mitigate this threat, I completed two rounds of axial coding and then member checked my results with a doctoral candidate in the West Chester
University of Pennsylvania’s EDD program. Using the codes I had identified during the initial open coding, this individual coded selected sections of the interview transcripts. We compared their findings to my coding results to determine the alignment and identification of categories and themes. These measures ensured the highest likelihood that the data collected would accurately reflect the findings from the study.

**Researcher’s Bias and Observer’s Paradox**

My positionality and authority create an ethical tension that I must address in my research design. This tension is especially present for participants who are teachers within the district in which I work. I hold a position of power and authority over these practitioners, and I must be mindful that participants may have concerns that their responses will influence my evaluation of their teaching practices.

In addition, participants from other districts may worry that I will share their beliefs with their school or district administrators. Teachers within and outside my district might feel pressured to participate in the study because I am in a position of influence and authority. In response, I developed protocols for solicitation, communication, and participation in my study that provide a safe opportunity for teachers to participate. Establishing trust and authenticity is essential to the success of my research. Finally, during the interview process, I reminded participants not to use identifying information to protect the anonymity of the participants.

**Procedures**

Using Creswell and Plano Clark’s (2017) recommended qualitative and quantitative data collection procedures, the following section details the study procedures, including data collection, study schedule, and data analysis. Specifically, this section outlines the procedures followed for recruitment and quantitative data collection during phase 1, the steps taken to
analyze the data and identify mathematical identity profile groups, and the procedures followed for collecting and interpreting the phase 2 qualitative data.

Procedure Overview

For each participating school district, the Superintendent of Schools or other district-designated administrators solicited participation from elementary teaching staff within the district. Each district-identified point person distributed the initial survey and follow-up solicitation communication that I provided. The district-identified person sent the initial solicitation email to all possible eligible teachers and copied me on all communications. The communications included the inclusion criteria, a copy of the consent form, and a link to the Qualtrics survey. After three weeks, district representatives distributed a second email soliciting participation. The survey remained open for an additional two weeks following the final solicitation.

Procedure for Phase 1 Quantitative Data Collection

Volunteer participants accessed and completed the survey via a link included in the solicitation email. The survey stopped participants who did not provide consent or did not meet the inclusion criteria before answering study-related questions. The inclusion criteria established common professional experiences among participants and ensured that all participants were current elementary math teachers. Inclusion criteria allow for a more accurate comparison of lived experiences while limiting non-related factors that may influence participants’ responses (Creswell & Plano Clark, 2017). In addition, the survey included a question soliciting participation in a follow-up interview by asking willing participants to provide their email addresses and consent for future contact.
Following the data collection window for the survey, I cleaned the data by removing incomplete responses. In addition, I removed responses in which the participant did not meet the inclusion criteria. Using the Statistical Package for Social Sciences (SPSS), I transposed the Likert-scale items from the survey into values of 1 to 5, with 1 representing strongly disagree and 5 representing strongly agree. I then reversed the scale for five questions for which the survey statements contained negative wording. For example, the statement, *I believe that solving math problems quickly is important*, was reversed so that a response of *strongly agree* was given a score of one.

I used the clean data to generate a Likert-scale data set composite score for participants’ overall measure of math identity using nine questions from the survey. Three of the nine questions came from statements validated from Op’t Eynde and De Corte’s (2003) questionnaire, while the other six were self-generated statements directly related to an individual's beliefs about their math ability. Creating a Likert-scale composite score by combining the results of four or more individual statements is an effective way to measure a character or personality trait in quantitative research (Boone & Boone, 2012).

I used SPSS to conduct descriptive statistical analysis to determine if the composite mathematical identity value represented a normal distribution. The data did follow a normal distribution with a mean of 32.5, a median of 33.0, and a strong linear correlation on a normal Q-Q plot. I then used the determined standard deviation of 5.6 to create three profile groups for mathematical identity. Group A was one or more standard deviations below the mean, Group B was within one standard deviation of the mean, and Group C was one standard deviation or more above the mean. Based on participants’ self-reported survey responses, these groups represent three unique mathematical identity profiles. The profiles may range from teachers with self-
identified negative mathematical identities (Group A) who believe that direct instruction, drill, and practice are the most effective instructional techniques to teachers with self-identified positive mathematical identities (Group C) who believe collaboration and active problem-solving are the most effective instructional practices.

**Procedure for Phase 2 Qualitative Data Collection**

Once I identified the three mathematical identity profiles, I created a list of participants who expressed a willingness to participate in follow-up interviews for each profile group. Group A contained four participants, Group B included 14 participants, and Group C had 6 participants. To further narrow the number of Group B participants, I identified four participants with a mathematical identity value within 1 point of the statistical mean. I then numbered the members of each group and used an Alexa to select two numbers from each profile group randomly. I used the prompt, *Alexa, pick a number between 1 and __*, and then repeated the prompt to select the second participant. If the same number was selected, I repeated the prompt until I got two unique selections.

I then emailed each chosen participant and asked them to choose a date and time that would work best for their interview. I sent each participant an email and Google Calendar invite that included the scheduled date, time, and unique link to the Zoom session I used to conduct the interview. Initially, three participants did not respond after 48 hours. In response, I sent follow-up emails to the three individuals. As a result, all but one participant scheduled their interviews within 24 hours. After four days, I used my procedures to randomly select an alternate participant to replace the individual who failed to schedule their interview. All interviews were scheduled and conducted within two weeks of the initial communication.
I conducted the semi-structured interviews through the Zoom platform. I thanked the participant and read the interview protocol to start each interview. The interview protocol asked participants to change their names to maintain anonymity and explained that the interview would be recorded. In addition, the protocol reviewed consent and reminded participants that they did not have to answer questions they did not want to answer. Upon verbal consent to continue, I started the video and audio recordings and completed the interviews. The interviews lasted between 22 and 28 minutes. Throughout the interviews, I checked for clarity by asking questions like; *can you expand on that*, or I would rephrase participants' comments and then ask if I interpreted their thoughts correctly. Following each interview, I generated a transcript and checked it for accuracy. I employed member checking by sending a copy of the transcript to participants to add comments if needed. Following confirmation of the accuracy of the transcript, I deleted audio and video recordings of the interviews and proceeded to analyze the data using inductive coding procedures.

**Data Collection Schedule**

Forty-eight participants were included in the quantitative phase of the study and six teachers took part in the second qualitative phase. The initial survey took approximately 15 minutes, and the follow-up semi-structured interviews were scheduled for 30 minutes each. Participants who completed the survey and the interview committed approximately 45 minutes to the study. The initial survey was available for five weeks from November through the start of December and interviews were conducted over two weeks at the end of January and into February.

There was a six-week period between the end of quantitative data collection and the scheduling of the qualitative interviews. The time between the survey data collection and the
interviews was longer than planned. This delay was the result of two unanticipated factors. First, it took longer than expected to analyze the quantitative data and generate the list of possible participants to interview for each profile group. Second, winter break fell between the end of the survey collection and interview scheduling. Because the participants worked in public schools, many were unavailable to communicate until they returned to work in January. In addition, my colleagues recommended that I give teachers two weeks to get back in the swing of their daily routines before scheduling interviews. Figure 3.2 represents the timeline for this study.

**Figure 3.2**

*Study Timeline*

<table>
<thead>
<tr>
<th>September 2023</th>
<th>October 2023</th>
<th>November 2023</th>
<th>December 2023</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obtain permission to conduct research.</td>
<td>Prepare solicitation communication</td>
<td>Send solicitation communication to participating districts.</td>
<td>End of Phase 1 data collection</td>
</tr>
<tr>
<td>Obtain IRB approval</td>
<td></td>
<td>Phase 1 Data collection</td>
<td>Initial Quantitative Data Analysis</td>
</tr>
<tr>
<td>January 2024</td>
<td>February 2024</td>
<td>March 2024</td>
<td>April 2024</td>
</tr>
<tr>
<td>Schedule Phase 2 interviews</td>
<td>Complete statistical data analysis of quantitative data</td>
<td>Discussion of findings</td>
<td>Presentation of findings</td>
</tr>
<tr>
<td>Complete Phase 2 interviews</td>
<td>Begin coding and qualitative data analysis.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Member check qualitative transcripts.</td>
<td>Complete coding and qualitative data analysis</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>March 2024</th>
<th>April 2024</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discussion of findings</td>
<td>Presentation of findings</td>
</tr>
</tbody>
</table>
Data Analysis and Coding Procedures

I completed data analysis for this study in two phases. In phase one, SPSS was used to analyze the quantitative survey responses with descriptive and inferential statistics. In phase two, I used Axial coding to identify common themes after transcribing the interviews. Finally, I used the identified themes from the qualitative data to explain statistically relevant findings from the initial quantitative analysis.

Quantitative Data Analysis

I used the Statistical Package for Social Sciences (SPSS) to analyze the collected quantitative data. As previously described, the survey data was imported into SPSS and cleaned. I analyzed each Likert-type survey item using descriptive statistics for central tendency, variability, and frequency. In addition, I used descriptive statistics to review the self-reported demographic data. Evaluating the mean, median, frequencies, and standard deviations for specific items is an effective technique for analyzing individual Likert-type data (Boone & Boone, 2012).

I reviewed the descriptive statistics results to determine which items revealed more significant response variation and gained insight into the average response value for each item. Furthermore, demographic data was analyzed to determine if the participants were a representative sample of the larger population. I generated one Likert-scale data set to represent participants' overall mathematical identity. As previously explained, nine items on the survey related to identifying an individual's mathematical identity were combined to create the Likert-scale data set. The composite mathematical identity data set had a minimum possible score of 9 and a maximum possible score of 45. The participants’ scores ranged from 23 to 44, with a mean of 32.5, a median of 33, and a standard deviation of 5.6.
I conducted additional inferential analysis using SPSS to determine if a relationship exist between the participants’ self-reported mathematical identity and their demographic information. Specifically, SPSS was used to determine if statistical relevance exists between age, teaching experience, grade level taught, and level of education with participants’ overall mathematical identity value. I conducted a one-way analysis of variance (ANOVA) to compare the variability in scores between participants’ mathematical identity values and their demographic data. The acceptable level of risk for the statistical analysis was 5% or a $p$-value of 0.05 or less. The ANOVA tests allows for the comparison of a continuous data set, like the participants’ math identity score, with categorical data. The demographic data was categorical because it asks participants to choose between groups for each variable. For example, participants selected if their age from the groups 20-25 years old, 26-30 years old, 31-35 years old and so forth.

Qualitative Data Analysis and Coding Procedures

In qualitative research, researchers use data to come to an understanding rather than to determine statistically relevant relationships (Cresswell & Guetterman, 2019). The qualitative data analysis for this study utilized Axial coding to analyze the interview transcripts. Axial coding allows codes and themes to emerge from an initial inductive coding and then connects the identified themes to literature or the research questions for a second round of deductive coding (Strauss & Corbin, 2003). The following is a description of the process used to code the qualitative data for this study.

The semi-structured interviews were conducted through Zoom to observe nonverbal communication that may have led to follow-up questions. To establish a rapport with the participants, I started the interview with a brief explanation of my doctoral journey, and I reminded the participants of the purpose of the study and the interview protocol. I reminded
participants that they could stop the interview at any time. During the interviews, I restated participants' ideas and asked for confirmation of interpretation as an embedded form of member checking. Following the interviews, I transcribed the audio recordings. I used member checking by providing copies of the transcripts to the participants to add comments for clarification if needed. Member checking the findings is used to co-construct common understanding and adds validity and reliability to findings explaining recognized case profiles (Creswell & Plano-Clark, 2017).

After member checking, I conducted two cycles of coding following axial coding methodology. I used inductive open coding on the first coding round which identified categories that emerged organically from the transcripts. For the second round of coding, I used the research questions and categories that emerged during the first round to identify overarching themes. I then recoded the transcripts using the overarching themes (Strauss & Corbin, 2003). I utilized Saldana’s (2015) procedures for the open coding and grouped codes into categories to discover emergent categories. The second round of coding helped validate the emergent categories by connecting them to the identified themes from the research questions. To add reliability to my coding procedures, I had a doctoral student in the West Chester University of Pennsylvania’s EDD program member check sections from selected transcripts. I compared and contrasted the codes created by the doctoral student with my own to check for agreement and alignment in my coding procedures.

**Item and Pattern Level Analysis**

Figure 3.4 provides an item analysis for each survey and interview question related to each research question. The item analysis shows that multiple data collection points are associated with each research question.
### Mixed Method Research Questions

*How does an elementary teacher’s mathematical identity affect their self-reported beliefs about effective math instruction?*

<table>
<thead>
<tr>
<th>Research Question</th>
<th>Questionnaire Items</th>
<th>Interview Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>RQ1 (Quant): What percent of educators surveyed report developing a positive versus negative mathematical identity?</td>
<td>Questions 12.2, 12.3, 12.5*, 12.8, 12.10, 12.11, 12.12, 13.1*, 13.2*</td>
<td></td>
</tr>
<tr>
<td>RQ2 (Quant): Is there a relationship between the reported demographics of teachers and their self-identified mathematical identities?</td>
<td>Questions 6-11 (Demographics Block)</td>
<td>Questions 12.2, 12.3, 12.5*, 12.8, 12.10, 12.11, 12.12, 13.1*, 13.2*</td>
</tr>
<tr>
<td>RQ3 (Qual) How are teachers’ mathematical identities influenced by their experiences as math students and educators?</td>
<td>Questions 12.1, 12.6, 12.9, 14.3</td>
<td>Questions 1, 2, 4, 5</td>
</tr>
<tr>
<td>RQ5 (Qual) What beliefs do teachers report about the importance of learning math, and how does this relate to the teachers’ mathematical identities?</td>
<td>Questions 13.3, 13.4, 13.5, 14.1</td>
<td>Question 4, 6, 8</td>
</tr>
</tbody>
</table>

*Indicates the scale was reversed during statistical analysis

**Note:** Appendix D includes copies of the items included in the survey and interview.
Informed Consent and Protection of Human Subjects

I received approval through West Chester University’s Institutional Review Board (IRB) to conduct this research. In addition, each participating district provided a letter of permission to conduct research with their district staff. Participation in this study was voluntary, and participants were not obligated to participate through administrative pressure. I used a neutral tone in crafting the solicitation communications, and the emails clearly stated that participation was optional. Appendix E includes a copy of the IRB approval.

Participants accessed and completed the survey via a link sent to them in an email. Teachers who participated in the survey saw the inclusion criteria questions and consent form at the beginning of the survey. Teachers who started the survey but did not provide consent or did not meet the inclusion criteria were directed to the end of the survey before answering study-related questions. The survey did include a question soliciting participation in a follow-up interview by asking participants to provide their email addresses if they were willing to be contacted to schedule an interview. Appendix F includes a copy of the consent form.

Participants may have provided identifiable information in the initial survey, and I collected video and audio recordings during the interview. To help mitigate this risk, I cleaned the survey data to remove identifiable information and deleted the interview recordings after completing transcription and member checking. In addition, participants may have felt uncomfortable sharing their beliefs about their mathematical identities and abilities. Participants feeling uncomfortable was most likely to occur while answering specific survey questions or during the interview process. To mitigate this risk, I reminded participants that they did not have to answer questions and could stop the interview at any time.
To address concerns about maintaining anonymity, Qualtrics was used to anonymize the survey data to protect participants' identities unless a participant volunteered for the phase 2 interview. The interview protocol included a reminder about not using identifiable data in responses and allowed participants the opportunity to turn off their videos. I deleted all audio and video recordings and participant emails after transcription, member-checking, and coding of the interviews. In my solicitation for participation, I clearly stated the purpose of my study and included information about how data would be collected and analyzed. Data was always securely collected and stored on password-protected two-factor authentication devices.

There was minimal psychological risk for participants feeling uncomfortable sharing their beliefs about their mathematical identities and preferred mathematical instruction strategies. A conflict of interest may exist because one of my participating districts is the district where I work as an administrator. Participants may feel concerned or worried about administrative evaluation influenced by their personal beliefs during the study.

To minimize this risk, the purpose of the study and how participant information was protected was communicated in the survey and interview protocols. In addition, communication to teachers in my district was sent from another district-identified contact to minimize the conflict of interest. I informed participants that they could withdraw from the study at any time or not answer any questions included in the survey or interview. I did not use the names of participants, schools, or school districts in the dissertation or any publications or presentations. I did not share identifiable information from participants with participating district administrators to protect them from potential conflicts of interest. In addition, I do not directly supervise any potential participants who meet the eligibility criteria for the study.
Summary

Chapter 3 of this dissertation presented the methodological design used to explore the impact of elementary teachers' mathematical identities on their perceptions of math instruction. Employing an explanatory sequential mixed-methods design, this study utilized quantitative data collected from a survey to identify participants' mathematical identities, followed by qualitative data collected from semi-structured interviews to provide depth and context to the initial quantitative findings. This chapter highlighted the importance of the mixed methods design in understanding the nuanced development and manifestation of teachers' mathematical identities within the sociocultural context of the classroom. The use of a mixed-methods approach allowed for a comprehensive exploration of the research problems, capturing both the broad perspectives obtained from quantitative data and the detailed insights provided by qualitative analysis.

In addition, Chapter 3 presented information about the participants and districts included in the study and outlined the procedures used for data collection and analysis. I provided details on how I completed quantitative data analysis to determine participants’ mathematical identities and analyzed qualitative results through coding to identify themes. This chapter presented potential threats to validity and reliability and the steps I took to mitigate these risks. Finally, I provided information on protecting participants' safety throughout the research process. Chapter IV will further discuss the data collection and results.
Chapter 4

Chapter 4 presents the results of this explanatory sequential mixed-methods study exploring the manifestation of teachers’ mathematical identities in their beliefs about elementary math instruction. An overview of the study’s sample is provided, then, in alignment with the study’s design, this chapter presents the results and analysis in conjunction with the associated research questions:

**Quantitative Research Questions**

RQ1: What percent of educators surveyed report developing a positive versus negative mathematical identity?

RQ2: Is there a relationship between the reported demographics of teachers and their self-identified mathematical identities?

**Qualitative Research Questions**

RQ3: How are teachers’ mathematical identities influenced by their experiences as math students and educators?

RQ4: How do teachers’ mathematical identities align with their preferences for instructional choices?

RQ5: What beliefs do teachers report about the importance of learning math, and how does this relate to the teachers’ mathematical identities?

**Overarching Research Question**

RQ Overarching: How does an elementary teacher’s mathematical identity affect their self-reported beliefs about effective math instruction?
Overview

In this chapter, I first present the quantitative data results, including a preliminary descriptive statistical analysis of the data collected from the questionnaire and a detailed description of the one-way between-groups analysis of variance (ANOVA) tests as part of the discussion. In congruence with an explanatory sequential design (Creswell & Plano-Clark, 2017), I further explain the quantitative results framed within Vygotsky’s sociocultural theory of learning and Sfard and Prusak’s (2005) mathematical identity theory. I analyze the data’s alignment with the theoretical framework of mathematical identity, which states that individuals construct their mathematical beliefs over time, and a diverse collection of mathematical identities exists within a population (Boaler & Greeno, 2000). This section concludes with an ANOVA relational evaluation of participants' demographics with the measure of their overall mathematical identities.

Following the quantitative discussion, I present the qualitative results through the lens of each qualitative research question. Using inductive and deductive coding, the analysis of six interviews identified common themes that provide context and further explain the quantitative findings. This chapter presents the qualitative results through Vygotsky’s sociocultural theoretical framework and provides evidence supporting the paradigm that past experiences shape teachers’ mathematical identities (John-Steiner & Mahn, 1996). I conclude the qualitative section by presenting results that align with research that suggests that teachers’ mathematical identities influence their beliefs about effective math instructional strategies (Bray, 2011; Stipek et al., 2001).

Finally, I analyze the quantitative and qualitative results in relation to the overarching research question, which explores elementary teachers’ mathematical identities and their overall
beliefs about effective math instruction. These results are presented last because of the question's complex nature, which requires combining both quantitative and qualitative data. Through this discussion, overarching themes emerge related to the role teachers past experiences played in shaping their beliefs about effective math instruction.

**Demographics of the Sample**

This study's population includes elementary teachers from eight public school districts throughout southeastern Pennsylvania, representing an estimated 550 teachers. During phase 1 of the study, I collected 48 valid responses (N=48) representing 8.7% of the population. The average age of the participants was 39.25 years, and the participants averaged 12.6 years of teaching experience. Of the 48 participants, 44 identified as female, and 43 had achieved a master’s degree as their highest level of education. Table 4.1 represents the participants’ demographics from phase 1 of the study, including gender, level of education, age range, and teaching experience.

During phase 2 of the study, six participants participated in semi-structured interviews, representing 12.5% of the study’s sample size. The six participants represent teachers from five different districts and six different schools. The participants ranged in age from early 20s to late 50s and worked with first through fifth-grade students. The participants came with varying professional experience; two were in their first five years of teaching, and two had more than 25 years of experience.
Table 4.1

Participants’ Demographics from Phase 1

<table>
<thead>
<tr>
<th>Demographic Characteristics</th>
<th>n</th>
<th>% of Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>3</td>
<td>6.3%</td>
</tr>
<tr>
<td>Female</td>
<td>44</td>
<td>91.7%</td>
</tr>
<tr>
<td>Prefer not to say</td>
<td>1</td>
<td>2.1%</td>
</tr>
<tr>
<td><strong>Level of Education</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Undergraduate Degree</td>
<td>5</td>
<td>10.4%</td>
</tr>
<tr>
<td>Master’s Degree</td>
<td>43</td>
<td>89.6%</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20-25</td>
<td>1</td>
<td>2.1%</td>
</tr>
<tr>
<td>26-30</td>
<td>9</td>
<td>18.8%</td>
</tr>
<tr>
<td>31-35</td>
<td>6</td>
<td>12.5%</td>
</tr>
<tr>
<td>36-40</td>
<td>4</td>
<td>8.3%</td>
</tr>
<tr>
<td>41-45</td>
<td>8</td>
<td>16.7%</td>
</tr>
<tr>
<td>46-50</td>
<td>6</td>
<td>12.5%</td>
</tr>
<tr>
<td>51-55</td>
<td>10</td>
<td>20.8%</td>
</tr>
<tr>
<td>56-60</td>
<td>3</td>
<td>6.3%</td>
</tr>
<tr>
<td>66 and up</td>
<td>1</td>
<td>2.1%</td>
</tr>
<tr>
<td><strong>Years of Teaching Experience</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-5 Years</td>
<td>8</td>
<td>16.7%</td>
</tr>
<tr>
<td>6-10 Years</td>
<td>11</td>
<td>22.9%</td>
</tr>
<tr>
<td>11-15 Years</td>
<td>5</td>
<td>10.4%</td>
</tr>
<tr>
<td>16-20 Years</td>
<td>8</td>
<td>16.7%</td>
</tr>
<tr>
<td>21-25 Years</td>
<td>6</td>
<td>12.5%</td>
</tr>
<tr>
<td>26-30 Years</td>
<td>8</td>
<td>16.7%</td>
</tr>
<tr>
<td>30+ Years</td>
<td>2</td>
<td>4.2%</td>
</tr>
</tbody>
</table>

Note: N count = 48 for each condition. All data is self-reported from the initial survey.
Quantitative Results

The quantitative data for this study was self-reported during phase 1 using the online questionnaire. The collected data represents participants' self-reported demographic characteristics and personal beliefs in response to a series of Likert scale questions related to mathematical identity. In this section, I present a preliminary analysis of the frequencies of reported beliefs from the Likert scale survey items. Following the initial analysis, I include the test results for the normal distribution of the measured mathematical identity value. Finally, I present the results associated with the study’s two quantitative research questions, exploring the percentage of participants who have developed a positive mathematical identity and the relationship between demographic characteristics and mathematical identity. I used IBM’s Statistical Package for Social Sciences (SPSS) version 29.0.2.0 to complete the quantitative analysis included in this section.

Preliminary Analysis

Due to mathematical identity development's complex and dynamic nature (Darragh, 2016), the preliminary analysis establishes important background information and context for understanding participants’ mathematical identities in relation to frequencies and distribution. When analyzing Likert Scale results, descriptive statistics, including the frequencies, medium, standard deviation, variance, and range, are appropriate (Pallant, 2020). I organized the results of this analysis into three sections from the initial survey. Section one included twelve survey items that measured participants’ current mathematical identities, section two included five survey items associated with beliefs about student math abilities, and the last section included six survey items related to beliefs about effective strategies and math instructional practices.
Preliminary Analysis of Section 1: Participant’s Mathematical Identities.

Individuals’ mathematical identities are constructed over time through lived experiences and are dynamic (Boaler & Selling, 2017; Boaler & Staples, 2008; Harper, 2019). Therefore, it is helpful to evaluate several items when determining participants’ mathematical identities. Section 1 of the questionnaire provided statements directly related to the manifestation of an individual’s mathematical identity. Using SPSS, I analyzed the individual Likert scale items (n=23) from section 1 of the survey to determine the medium, standard deviation, variance, and ranges associated with each statement. Table 4.2 includes the results of this analysis. Participants chose on a Likert scale from strongly disagree to strongly agree for each item. I converted participants' responses to a five-point scale with one equal to strongly disagree and five equal to strongly agree. In addition, the range from 1 to 5 represents the number of unique responses to each survey item.

Analyzing this data reveals results that illuminate the complexity of studying mathematical identity. For example, one item in this section yielded minimal response variance. Regarding the statement, I believe that math is useful in my daily life; 40 out of 48 respondents strongly agreed, while the other eight respondents somewhat agreed. This result indicates that regardless of mathematical identity, participants see value in the usefulness of math in their daily lives. Additionally, this analysis revealed that most participants (over 87%) reported that they strongly agreed or agreed with the statements: I enjoy teaching math and I am confident in my mathematical abilities as an educator. This data indicates that participants’ mathematical identities do not affect their enjoyment of teaching elementary mathematics or their confidence in their mathematical abilities as educators.
Two additional items of note were the following: I believe that solving math problems quickly is important, and I believe that getting the right answer is the most important thing in math. Research commonly recognizes these statements as quality markers in uncovering an individual’s mathematical identity, with respondents who agree with these statements exhibiting a more negative or fixed mathematical identity (Boaler & Staples, 2008; Drake et al., 2001). Both statements showed significant variance in responses, indicating that diversity exists within the participants’ developed mathematical identities.

Table 4.2

Descriptive Statistics from Section 1 of the Survey

<table>
<thead>
<tr>
<th>Item</th>
<th>Median</th>
<th>Std. Dev.</th>
<th>Variance</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>I enjoyed math class when I was in school.</td>
<td>4.00</td>
<td>1.434</td>
<td>2.057</td>
<td>5</td>
</tr>
<tr>
<td>I believe that I am good at math.</td>
<td>4.00</td>
<td>.967</td>
<td>.936</td>
<td>4</td>
</tr>
<tr>
<td>I believe that math is useful in my daily life.</td>
<td>5.00</td>
<td>.377</td>
<td>.142</td>
<td>2</td>
</tr>
<tr>
<td>I believe that solving math problems quickly is important.</td>
<td>4.00</td>
<td>1.253</td>
<td>1.570</td>
<td>5</td>
</tr>
<tr>
<td>I believe that getting the right answer is the most important thing in math.</td>
<td>3.00</td>
<td>1.242</td>
<td>1.542</td>
<td>5</td>
</tr>
<tr>
<td>I believe that my math education was effective.</td>
<td>4.00</td>
<td>1.169</td>
<td>1.366</td>
<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Item</th>
<th>Median</th>
<th>Std. Dev.</th>
<th>Variance</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>I enjoy teaching math.</td>
<td>5.00</td>
<td>.832</td>
<td>.692</td>
<td>4</td>
</tr>
<tr>
<td>I am confident in my mathematical abilities as an educator.</td>
<td>4.00</td>
<td>.805</td>
<td>.648</td>
<td>4</td>
</tr>
<tr>
<td>I was a good math student in school.</td>
<td>4.00</td>
<td>1.153</td>
<td>1.329</td>
<td>5</td>
</tr>
<tr>
<td>I can understand even the most difficult mathematical concepts.</td>
<td>3.00</td>
<td>1.125</td>
<td>1.266</td>
<td>5</td>
</tr>
<tr>
<td>I am interested in mathematics.</td>
<td>4.00</td>
<td>1.024</td>
<td>1.048</td>
<td>4</td>
</tr>
<tr>
<td>I like to learn new ways to solve math problems.</td>
<td>4.00</td>
<td>.922</td>
<td>.849</td>
<td>5</td>
</tr>
</tbody>
</table>

Note: For the median, one equals strongly disagree, and five represents strongly agree.
Preliminary Analysis of Section 2: Beliefs about Student Math Abilities. Educators’ beliefs about their students are another way to get a glimpse into the mathematical identity of an individual. Often, teachers who have developed a negative mathematical ability believe that some students are born with math brains and are inherently better at math (Boaler & Greeno, 2000). Section two of the questionnaire provided statements directly related to educators’ beliefs about math students. The statements help uncover teachers' intrinsic thoughts about math students and the importance of how students engage in math. Using SPSS, I analyzed the individual Likert items from section two of the survey to determine the medium, standard deviation, variance, and ranges associated with each statement. Table 4.3 includes the results of this analysis. For each item, participants chose from strongly disagree to strongly agree. I converted participants' responses to a five-point scale with one equal to strongly disagree and five representing strongly agree. In addition, the range from 1 to 5 represents the number of unique responses to each survey item.

Table 4.3

Descriptive Statistics from Section 2 of the Survey

<table>
<thead>
<tr>
<th>Statement</th>
<th>Median</th>
<th>Std. Deviation</th>
<th>Variance</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>I believe that some people just don't get math.</td>
<td>2.00</td>
<td>1.201</td>
<td>1.443</td>
<td>5</td>
</tr>
<tr>
<td>I believe that some people are born with brains that work in ways that are just better for math and science.</td>
<td>4.00</td>
<td>1.282</td>
<td>1.644</td>
<td>5</td>
</tr>
<tr>
<td>I believe that it is important that people are able to explain their reasoning in math.</td>
<td>4.50</td>
<td>.917</td>
<td>.840</td>
<td>5</td>
</tr>
<tr>
<td>I believe that people see value in what they learn in math class.</td>
<td>4.00</td>
<td>.915</td>
<td>.836</td>
<td>5</td>
</tr>
<tr>
<td>I believe that the concepts people learn in math class are vital to their success in life.</td>
<td>4.00</td>
<td>.683</td>
<td>.466</td>
<td>4</td>
</tr>
</tbody>
</table>

Note: For the median, one is equal to strongly disagree, and five represents strongly agree.
Significant variance (1.433 and 1.644) exists for two items from section two of the survey. In response to the statement, *I believe that some people just don’t get math* (variance = 1.443); 29 (60.5%) respondents strongly disagreed or disagreed, while 12 (25%) respondents agreed or strongly agreed. In addition, 11 (22.9%) participants disagreed with the statement; *I believe that some people are born with brains that work in ways that are just better for math and science* (variance = 1.644), while 28 (58.4%) agreed. With a standard deviation for both statements of 1.2, the data indicates significant disagreement among participants' beliefs about the inherent nature of math ability in students. Educators' experiences and beliefs influence their thoughts about students' math abilities and commonly represent their established mathematical mindset (Bray, 2011).

**Preliminary Analysis of Section 3: Beliefs about Effective Math Instruction.**

Teachers’ mathematical identities also manifest in their beliefs about effective teaching strategies and preferred instructional practices (Stipek et al., 2001). Teachers who have developed a more negative mathematical identity tend to hold more traditional beliefs, emphasizing student computational skills, algorithmic thinking, and getting the correct answer (Stipek et al., 2001). Section three of the questionnaire included items related to educators’ beliefs about effective instructional strategies and the purpose of teaching math. Using SPSS, I analyzed the individual Likert items from section three of the survey to determine the medium, standard deviation, variance, and ranges associated with each statement. Table 4.4 includes the results of this analysis. For each item, participants chose from strongly disagree to strongly agree. I converted participants' responses to a five-point scale with one equal to strongly disagree and five representing strongly agree. In addition, the range from 1 to 5 represents the number of unique responses to each survey item.
The preliminary analysis of the items from section three of the survey reveals some common beliefs among participants. All participants (n=48) agreed with the statement; *I believe that it is my responsibility to build my students’ beliefs that they are good at math.* This finding is noteworthy because participants value fostering positive mathematical identities in their students regardless of their mathematical identities. Furthermore, there was 95% (n=46) agreement among participants regarding the item; *I believe that feedback on how students engage with math problems that are not centered on the final answer is valuable.*

**Table 4.4**

*Descriptive Statistics from Section 3 of the Survey*

<table>
<thead>
<tr>
<th>Statement</th>
<th>Median</th>
<th>Std. Dev</th>
<th>Variance</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>I believe that it is my responsibility to build my students' beliefs that they are good at math.</td>
<td>5.00</td>
<td>.438</td>
<td>.191</td>
<td>2</td>
</tr>
<tr>
<td>I like to teach using the same strategies that I was exposed to as a math student.</td>
<td>3.00</td>
<td>1.229</td>
<td>1.510</td>
<td>5</td>
</tr>
<tr>
<td>I believe that expectations for math instruction have changed throughout my career.</td>
<td>5.00</td>
<td>.789</td>
<td>.622</td>
<td>5</td>
</tr>
<tr>
<td>I prefer instructional strategies that maximize collaborative problem solving.</td>
<td>4.00</td>
<td>.967</td>
<td>.934</td>
<td>4</td>
</tr>
<tr>
<td>I believe that students learn best when they engage in discussions about problem solving.</td>
<td>5.00</td>
<td>1.005</td>
<td>1.010</td>
<td>4</td>
</tr>
<tr>
<td>I believe that feedback on how students engage with math problems that are not centered on the final answer is valuable.</td>
<td>4.50</td>
<td>.703</td>
<td>.495</td>
<td>3</td>
</tr>
</tbody>
</table>

*Note: For the median, one equals strongly disagree, and five represents strongly agree.*

These statements align with the goals of the mathematical reform movement, emphasizing dialog, problem-solving, and fostering a growth mindset in math classrooms (NCTM, 2018). The results from the statement; *I believe that expectations for math instruction have changed throughout my career,* in which 95.8% (n=46) of respondents agreed or strongly
agreed, also suggest that participants recognize a shift toward the ideals of the mathematical reform movement. Finally, the data shows significant variance and range regarding the statement; *I like to teach using the same strategies that I was exposed to as a math student.* There is almost an equal split, with 17 respondents disagreeing, 18 agreeing, and 13 undecided. These variations and range in responses suggest that there may be a connection between the mathematical identities of the participants and their preferred teaching strategies.

**Preliminary Analysis Results.** After completing the preliminary survey analysis using descriptive statistics, the results indicate that further explanation is required to understand the complex manifestation of participants’ mathematical identities. Specifically, the observed variance and range associated with preferred teaching strategies, beliefs about students’ abilities, and beliefs about the goals of math instruction require additional context. Appendix G includes the complete frequencies and percentages for each item response from the survey.

**Measuring Participants’ Mathematical Identities**

My first quantitative research question explores the percentage of participants who have developed a positive versus negative mathematical identity. To investigate this question, I combined the scores of nine survey items into a continuous data set representing participants’ total mathematical identity value. The survey statements used to generate the Likert scale data set were: *I believe that I am good at math, I believe that math is useful in my daily life, I believe that getting the right answer is the most important thing in math, I am confident in my mathematical abilities as an educator, I can understand even the most difficult mathematical concepts, I am interested in mathematics, I like to learn new ways to solve math problems, I believe that some people just don't get math, and I believe that students learn best when they engage in discussions about problem-solving.*
Once combined, the lowest possible mathematical identity score was a 9, and the highest possible score was a 45. I used SPSS to run descriptive statistics calculating the mean, medium, and standard deviation. The results showed that participants’ total mathematical identity value had a mean of 32.5 and a standard deviation of 5.6. The lowest observed value was 23, and the highest was 44, giving a range of 21 among the participants. The most frequently observed total mathematical identity score was 33, representing 10.4% of the participants.

**Checking for Normal Distribution.** Given the continuous nature of the data set, I tested for a normal distribution of the results. I found that the total mathematical identity value data set did represent a normal distribution. With a mean of 32.5 and a medium of 33, a skewness result of .143, and a kurtosis value of -.697, the results fall well within the expected values to indicate a normal distribution (Pallant, 2020). Figure 4.1 includes the descriptive statistics results for the total mathematical identity value data set and shows the normal distribution of the mathematical identity scores on a histogram and a normal Q-Q plot comparing the data to an expected normal distribution line.

**Research Question 1: Participants’ Mathematical Identities**

Determining an exact measure of an individual’s mathematical identity is complex. Mathematical identities are constructed and reified over time through lived experiences (Sfard & Prusak, 2005). Furthermore, an individual’s mathematical identity is fluid and can be influenced by daily interactions as it is constructed (Wood, 2013). Research suggests that combining multiple items into a Likert scale data set can help identify an individual’s mathematical identity (Boone & Boone, 2012; Op’t Eynde & De Corte, 2003). In this section, I present the results for the research question: What percent of educators surveyed report developing a positive versus negative mathematical identity?
Figure 4.1

Normal Distribution of Total Mathematical Identity Value

<table>
<thead>
<tr>
<th>Total Math Identity Value</th>
<th>Statistic</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>32.5208</td>
<td>.80721</td>
</tr>
<tr>
<td>95% Confidence Interval</td>
<td>Lower</td>
<td>30.8969</td>
</tr>
<tr>
<td>for Mean</td>
<td>Bound</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Upper</td>
<td>34.1447</td>
</tr>
<tr>
<td></td>
<td>Bound</td>
<td></td>
</tr>
<tr>
<td>5% Trimmed Mean</td>
<td>32.4444</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>33.0000</td>
<td></td>
</tr>
<tr>
<td>Variance</td>
<td>31.276</td>
<td></td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>5.59251</td>
<td></td>
</tr>
<tr>
<td>Minimum</td>
<td>23.00</td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>44.00</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>21.00</td>
<td></td>
</tr>
<tr>
<td>Interquartile Range</td>
<td>8.00</td>
<td></td>
</tr>
<tr>
<td>Skewness</td>
<td>.143</td>
<td>.343</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>-.697</td>
<td>.674</td>
</tr>
</tbody>
</table>

Histogram of Total Mathematical Identity Value Distribution & Normal Q-Q Plot
Results of Participants’ Mathematical Identities. Determining the overall percentage of participants with a positive vs negative mathematical identity is challenging due to the dynamic nature of identity development. In addition, the survey results and measure of participants' overall mathematical identity are based on self-reported survey responses and do not represent a normed value on a known scale. However, I can compare participants' mathematical identities along the measured continuum because the survey results exhibited a normal distribution. I calculated one standard deviation range from the mean to complete this evaluation. Participants with a total mathematical identity value between 27 and 37 fell within one standard deviation of the mean. Representing 62.5% (n=30) of the participants, these individuals represent the participants who exhibit characteristics of both a positive and negative mathematical identity.

Nine participants (18.8%) had a total mathematical identity value greater than 37. These participants represent individuals with the most positive measured mathematical identity. They responded in agreement to the items: I believe that I am good at math, I believe that math is useful in my daily life, I am confident in my mathematical abilities as an educator, I can understand even the most difficult mathematical concepts, I am interested in mathematics, I like to learn new ways to solve math problems, and I believe that students learn best when they engage in discussions about problem-solving and disagree with the statements; I believe that getting the right answer is the most important thing in math and I believe that some people just don't get math. In addition, two of the nine participants had total mathematical identity values at or above 43. These two participants represent the top 4% of the sample and have a total mathematical identity value greater than two standard deviations from the mean.

In contrast, I determined that nine participants (18.8%) had a mathematical identity value of less than 27. These participants represent individuals with the most negative or fixed
mathematical identity. They responded in disagreement to the items: *I believe that I am good at math, I believe that math is useful in my daily life, I am confident in my mathematical abilities as an educator, I can understand even the most difficult mathematical concepts, I am interested in mathematics, I like to learn new ways to solve math problems, and I believe that students learn best when they engage in discussions about problem-solving* and agree with the statements; *I believe that getting the right answer is the most important thing in math* and *I believe that some people just don't get math*. Unlike the positive math identity group, zero of the nine participants from this group had a total mathematical identity value of 21 or less, representing two standard deviations from the mean.

In summary, participants’ overall mathematical identity measure falls along a normally distributed continuum. These results indicate that, within the sample, I found that about 19% of participants have developed a more negative mathematical identity, 19% have developed a more positive mathematical identity, and about 62% exhibit characteristics of both. Finally, I found that the participants who self-reported a positive identity had a slightly higher range, with two individuals’ scores being two standard deviations above the mean.

**Research Question 2: Mathematical Identity and Demographics**

Researchers often consider demographic data when studying mathematical identities, and studies have found that demographics can influence the development of individuals’ mathematical beliefs (Empson, 2003; Rodriguez et al., 2004). For this research question, I examined whether a relationship exists between the participants' reported demographics and their self-identified mathematical identities. I hypothesized that a relationship exists between the teachers’ demographics and total mathematical identity value. The null hypothesis is that a
relationship does not exist between the teachers’ demographics and total mathematical identity value.

Using SPSS, I conducted a one-way-between-groups analysis of variance (ANOVA) to determine if a statistically significant relationship exists. A one-way-between-group ANOVA test is appropriate because the independent demographic variables are categorical with three or more groups, and the dependent variable, the total mathematical identity value, is a continuous data set (Pallant, 2020). Furthermore, the between-groups ANOVA is appropriate when the participants are unique to each group, as is the case with the collected demographic data (Pallant, 2020). Finally, the study met the assumptions for using an ANOVA evaluation due to the normal distribution of the total math identity value (Pallant, 2020).

To investigate this research question, I compared the participants' age, years of teaching experience, highest level of education, and grade level taught with their total mathematical identity value. I did not evaluate the gender demographic because the study did not meet the necessary n-count criteria, with only four participants reporting a gender other than female. Furthermore, I had to check Levene’s test for homogeneity of variances, which tests the variance in scores for each demographic category group (Pallant, 2020). The homogeneity test revealed that each demographic variable had a Sig. value greater than .05, validating the ANOVA results by not violating the homogeneity assumption.

**Relationship Between Age and Total Mathematical Identity Value.** I conducted a one-way between-groups analysis of variance to explore the impact of age on self-reported mathematical identity value as measured by the study’s questionnaire. The study divided participants into nine groups according to their age (Group 1: 20 to 25; Group 2: 26 to 30; Group 3: 31 to 35; Group 4: 36 to 40; Group 5: 41 to 45; Group 6: 46 to 50; Group 7: 51 to 55; Group 8:
With a Sig. value of .712, there was no statistically significant difference at the $p < .05$ level in total mathematical identity values for the different age groups. As a result, the null hypothesis cannot be rejected. Table 4.5 includes the ANOVA results between the age of the participant and their total mathematical identity value.

**Table 4.5**

*ANOVA Results of Age of Participant and Total Mathematical Identity Value*

<table>
<thead>
<tr>
<th>Age Groups</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>95% Confidence Interval for Mean</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-25</td>
<td>1</td>
<td>28.0000</td>
<td>.</td>
<td>.</td>
<td>28.00</td>
<td>28.00</td>
<td>28.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25-30</td>
<td>9</td>
<td>33.4444</td>
<td>4.85054</td>
<td>1.61685</td>
<td>29.7160</td>
<td>37.1729</td>
<td>25.00</td>
<td>40.00</td>
<td></td>
</tr>
<tr>
<td>31-35</td>
<td>6</td>
<td>35.3333</td>
<td>3.55903</td>
<td>1.45297</td>
<td>31.5984</td>
<td>39.0683</td>
<td>30.00</td>
<td>41.00</td>
<td></td>
</tr>
<tr>
<td>36-40</td>
<td>4</td>
<td>32.5000</td>
<td>9.67815</td>
<td>4.83908</td>
<td>17.0999</td>
<td>47.9001</td>
<td>24.00</td>
<td>44.00</td>
<td></td>
</tr>
<tr>
<td>41-45</td>
<td>8</td>
<td>33.2500</td>
<td>6.92305</td>
<td>2.44767</td>
<td>27.4622</td>
<td>39.0378</td>
<td>23.00</td>
<td>42.00</td>
<td></td>
</tr>
<tr>
<td>46-50</td>
<td>6</td>
<td>28.8333</td>
<td>4.53505</td>
<td>1.85143</td>
<td>24.0741</td>
<td>33.5926</td>
<td>23.00</td>
<td>36.00</td>
<td></td>
</tr>
<tr>
<td>51-55</td>
<td>10</td>
<td>32.0000</td>
<td>5.92546</td>
<td>1.87380</td>
<td>27.7612</td>
<td>36.2388</td>
<td>26.00</td>
<td>43.00</td>
<td></td>
</tr>
<tr>
<td>56-60</td>
<td>3</td>
<td>31.6667</td>
<td>1.52753</td>
<td>.88192</td>
<td>27.8721</td>
<td>35.4612</td>
<td>30.00</td>
<td>33.00</td>
<td></td>
</tr>
<tr>
<td>66 and up</td>
<td>1</td>
<td>36.0000</td>
<td>.</td>
<td>.</td>
<td>36.00</td>
<td>36.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>48</td>
<td>32.5208</td>
<td>5.59251</td>
<td>.80721</td>
<td>30.8969</td>
<td>34.1447</td>
<td>23.00</td>
<td>44.00</td>
<td></td>
</tr>
</tbody>
</table>

**ANOVA**

<table>
<thead>
<tr>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>$F$</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>178.424</td>
<td>8</td>
<td>22.303</td>
<td>.673</td>
</tr>
<tr>
<td>Within Groups</td>
<td>1291.556</td>
<td>39</td>
<td>33.117</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1469.979</td>
<td>47</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note: All data was self-reported from the study’s questionnaire.*
Relationship Between Teaching Experience and Total Mathematical Identity Value.

I conducted a one-way between-groups analysis of variance to explore the impact of years of teaching experience on self-reported mathematical identity value as measured by the study’s questionnaire. The study divided participants into seven groups according to their self-reported years of teaching experience (Group 1: 1 to 5 years; Group 2: 6 to 10; Group 3: 11 to 15; Group 4: 16 to 20; Group 5: 21 to 25; Group 6: 26 to 30; Group 7: 31 and above). With an Sig. value of .637, there was no statistically significant difference at the p < .05 level in total mathematical identity values for the different years of experience groups. As a result, I did not reject the null hypothesis. Table 4.6 includes the ANOVA results between the age of the participant and their total mathematical identity value.

### Table 4.6

ANOVA Results of Years of Teaching Experience and Total Mathematical Identity Value

<table>
<thead>
<tr>
<th>Yrs Teaching Exp.</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-5</td>
<td>8</td>
<td>32.5000</td>
<td>4.95696</td>
<td>1.75255</td>
<td>28.3559</td>
<td>36.6441</td>
<td>25.00</td>
<td>40.00</td>
</tr>
<tr>
<td>6-10</td>
<td>11</td>
<td>33.0000</td>
<td>5.11859</td>
<td>1.54331</td>
<td>29.5613</td>
<td>36.4387</td>
<td>23.00</td>
<td>41.00</td>
</tr>
<tr>
<td>11-15</td>
<td>5</td>
<td>35.0000</td>
<td>7.21110</td>
<td>3.22490</td>
<td>26.0462</td>
<td>43.9538</td>
<td>24.00</td>
<td>44.00</td>
</tr>
<tr>
<td>16-20</td>
<td>8</td>
<td>32.1250</td>
<td>7.49166</td>
<td>2.64870</td>
<td>25.8618</td>
<td>38.3882</td>
<td>23.00</td>
<td>42.00</td>
</tr>
<tr>
<td>21-25</td>
<td>6</td>
<td>32.8333</td>
<td>5.34478</td>
<td>2.18200</td>
<td>27.2243</td>
<td>38.4423</td>
<td>28.00</td>
<td>43.00</td>
</tr>
<tr>
<td>26-30</td>
<td>8</td>
<td>29.5000</td>
<td>4.00000</td>
<td>1.41421</td>
<td>26.1559</td>
<td>32.8441</td>
<td>25.00</td>
<td>36.00</td>
</tr>
<tr>
<td>30+</td>
<td>2</td>
<td>36.5000</td>
<td>6.36396</td>
<td>4.50000</td>
<td>-20.6779</td>
<td>93.6779</td>
<td>32.00</td>
<td>41.00</td>
</tr>
<tr>
<td>Total</td>
<td>48</td>
<td>32.5208</td>
<td>5.59251</td>
<td>.80721</td>
<td>30.8969</td>
<td>34.1447</td>
<td>23.00</td>
<td>44.00</td>
</tr>
</tbody>
</table>

**ANOVA**

<table>
<thead>
<tr>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>139.771</td>
<td>6</td>
<td>23.295</td>
<td>.718</td>
</tr>
<tr>
<td>Within Groups</td>
<td>1330.208</td>
<td>41</td>
<td>32.444</td>
<td></td>
</tr>
</tbody>
</table>

*Note: All data was self-reported from the study’s questionnaire.*
Relationship Between Highest Level of Education and Total Mathematical Identity

**Value.** I conducted a one-way between-groups analysis of variance to explore the impact of the highest level of education on self-reported mathematical identity value as measured by the study’s questionnaire. The study divided participants into two groups according to their self-reported highest level of education (Group 1: Undergraduate Degree; Group 2: Master’s Degree or Master’s Equivalency). With an Sig. value of .894, there was no statistically significant difference at the p < .05 level in total mathematical identity values for the two groups. As a result, the null hypothesis cannot be rejected. Table 4.7 includes the ANOVA results between the highest level of education of the participant and their total math identity value.

**Table 4.7**

*ANOVA Results of Highest Level of Education and Total Mathematical Identity Value*

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>95% Confidence Interval for Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower Bound</td>
</tr>
<tr>
<td>Undergraduate degree</td>
<td>5</td>
<td>32.2000</td>
<td>4.91935</td>
<td>2.2000</td>
<td>26.0918</td>
</tr>
<tr>
<td>Master's Degree or Master's Equivalent</td>
<td>43</td>
<td>32.5581</td>
<td>5.71674</td>
<td>.87179</td>
<td>30.7988</td>
</tr>
<tr>
<td>Total</td>
<td>48</td>
<td>32.5208</td>
<td>5.59251</td>
<td>.80711</td>
<td>30.8969</td>
</tr>
</tbody>
</table>

**ANOVA**

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>.575</td>
<td>1</td>
<td>.575</td>
<td>.018</td>
<td>.894</td>
</tr>
<tr>
<td>Within Groups</td>
<td>1469.405</td>
<td>46</td>
<td>31.944</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1469.979</td>
<td>47</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note: All data was self-reported from the study's questionnaire.*
Relationship Between Grade Level Taught and Total Mathematical Identity Value. I conducted a one-way between-groups analysis of variance to explore the impact of the grade level taught on self-reported mathematical identity value as measured by the study’s questionnaire. The study divided participants into five groups according to their self-reported grade level taught (Group 1: First Grade; Group 2: Second Grade; Group 3: Third Grade; Group 4: Fourth Grade; Group 5: Fifth Grade). With an Sig. value of .489, there was no statistically significant difference at the p < .05 level in total mathematical identity values for the grade level taught. As a result, the null hypothesis cannot be rejected. Table 4.8 includes the ANOVA results between the participants’ grade level and their total mathematical identity value.

Summary. Research question two examined whether a relationship exists between the participants' reported demographics and mathematical identities. Statistical analysis revealed no significant relationship between participants’ mathematical identity value and demographic categories. As a result, the null hypotheses could not be rejected. This result indicates a further need to explain the observed differences in mathematical identities among the participants.

Qualitative Results

To better explain the results from the quantitative analysis, In this section, I analyze the qualitative data gleaned from six semi-structured interviews. I conducted these interviews to add perspective and context to the quantitative findings that suggest that past experiences impact the development of an individual's mathematical identity and beliefs about math instruction. I start with a review of the methods for selecting the interview participants and present basic participant demographic information. I share the common themes that emerged from the coding process and then analyze these themes within the context of the three qualitative research questions. This section provides insights into how past experiences influenced the development of participants’
mathematical identities and examines how individuals’ mathematical identities influence their preferred instructional strategies and beliefs about effective math instruction.

Table 4.8

ANOVA Results of Grade Level Taught and Total Mathematical Identity Value

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Grade</td>
<td>6</td>
<td>32.333</td>
<td>5.24087</td>
<td>2.13957</td>
<td>26.8334</td>
<td>37.8333</td>
<td>24.00</td>
<td>40.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2nd Grade</td>
<td>11</td>
<td>29.727</td>
<td>5.34960</td>
<td>1.61296</td>
<td>26.1334</td>
<td>33.3212</td>
<td>23.00</td>
<td>42.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3rd Grade</td>
<td>6</td>
<td>34.333</td>
<td>6.37704</td>
<td>2.60342</td>
<td>27.6410</td>
<td>41.0256</td>
<td>25.00</td>
<td>43.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4th Grade</td>
<td>6</td>
<td>34.500</td>
<td>6.47302</td>
<td>2.64260</td>
<td>27.7070</td>
<td>41.2930</td>
<td>24.00</td>
<td>41.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5th Grade</td>
<td>8</td>
<td>32.250</td>
<td>6.73477</td>
<td>2.38110</td>
<td>26.6196</td>
<td>37.8804</td>
<td>23.00</td>
<td>44.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>37</td>
<td>32.216</td>
<td>5.96348</td>
<td>.98039</td>
<td>30.2279</td>
<td>34.2045</td>
<td>23.00</td>
<td>44.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ANOVA

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>126.422</td>
<td>4</td>
<td>31.605</td>
<td>.877</td>
<td>.489</td>
</tr>
<tr>
<td>Within Groups</td>
<td>1153.848</td>
<td>32</td>
<td>36.058</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1280.270</td>
<td>36</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: All data was self-reported from the study’s questionnaire.

Qualitative Sample Selection

I collected the qualitative data during phase two of the study through semi-structured interviews in which I selected six of the 48 participants from phase one to participate. To identify
the six interview participants, I grouped the 48 participants into three mathematical identity
groups based on their total mathematical identity value. Group A included nine teachers who fell
in the lowest 19% of all participants for mathematical identity value (math identity value less
than 28). Group B included thirty participants who fell within one standard deviation of the mean
for their measure of total mathematical identity value (math identity value from 28 to 37).
Finally, Group C included the top 19% (n=9) of participants with a total mathematical identity
value above one standard deviation from the mean (math identity value greater than 37).

For each group, I made a list of participants who indicated a willingness to participate in
follow-up interviews. Group A had four willing participants, group B had fourteen willing
participants, and group C had six willing participants. I randomly selected two individuals from
each group, transcribed the interviews, and coded the transcripts. After two requests, one
randomly selected participant from group C did not respond to my requests to schedule an
interview. As a result, I randomly selected another participant from the group C pool.

After I completed and transcribed all interviews, copies of the transcripts were provided
to the participants to check for accuracy and clarity. Two of the participants did not provide
additional comments. One participant said, “This transcript looks good!, and another participant
responded, “While I always hope I make sense, I think this captures the essence of it!” Finally,
two participants did add additional comments. One participant removed all of the “ums” and
additional “likes” that they said. This participant responded, “I skimmed and edited most of it,
but I feel as though it may not be really needed anyway!” The other participant added clarifying
thoughts to eight responses and said, “I just added some comments to a few of my responses.”
Their comments added additional context to help frame their responses. In the following section,
I describe the demographics of the six interview participants.
**Qualitative Phase Participants’ Demographics**

Table 4.9 identifies the six participants from the interview phase of this study. The table includes the participants’ pseudonyms, gender, education level, age range, years of teaching experience range, grade levels taught, mathematical identity score, and assigned mathematical identity group. Throughout this section, I refer to the participants by their chosen pseudonyms to protect their identity and maintain confidentiality. In addition, I changed the name of any district, school, and student that participants referenced to maintain confidentiality.

**Table 4.9**

*Qualitative Participants’ Demographics*

<table>
<thead>
<tr>
<th>Pseudonym</th>
<th>Gender</th>
<th>Education Level</th>
<th>Age Range</th>
<th>Teaching Experience in Years</th>
<th>Grade Levels Taught</th>
<th>Total Math Identity Score</th>
<th>Math Identity Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abigail</td>
<td>Female</td>
<td>Master's Degree</td>
<td>26-30</td>
<td>1-5</td>
<td>3rd</td>
<td>25</td>
<td>Group A</td>
</tr>
<tr>
<td>Erin</td>
<td>Female</td>
<td>Master's Degree</td>
<td>46-50</td>
<td>26-30</td>
<td>2nd</td>
<td>25</td>
<td>Group A</td>
</tr>
<tr>
<td>Ann</td>
<td>Female</td>
<td>Undergraduate Degree</td>
<td>26-30</td>
<td>1-5</td>
<td>2nd</td>
<td>32</td>
<td>Group B</td>
</tr>
<tr>
<td>Maria</td>
<td>Female</td>
<td>Master's Degree</td>
<td>56-60</td>
<td>31+</td>
<td>1st, 2nd, 3rd, 4th</td>
<td>32</td>
<td>Group B</td>
</tr>
<tr>
<td>Evelyn</td>
<td>Female</td>
<td>Master's Degree</td>
<td>26-30</td>
<td>6-10</td>
<td>3rd, 4th, 5th</td>
<td>38</td>
<td>Group C</td>
</tr>
<tr>
<td>Iris</td>
<td>Female</td>
<td>Master's Degree</td>
<td>51-55</td>
<td>31+</td>
<td>4th</td>
<td>41</td>
<td>Group C</td>
</tr>
</tbody>
</table>

*Note: All data shown was self-reported from the initial survey*
Each interview participant brought unique experiences and perspectives. Two teachers are in the first five years of their careers, while two teachers have over thirty years in the classroom. The participants had diverse professional experiences that they referenced throughout their interviews. The following is a brief profile description for each participant compiled from self-reported information on the questionnaire and gleaned from the interview transcripts.

**Abigail.** Abigail is a reasonably new teacher with less than five years of experience. In her mid-to-late twenties, Abigail expressed excitement and thoughtfulness throughout her interview. Abigail’s teaching experience has been exclusively in 3rd grade, and she holds a Pennsylvania teaching certificate for pre-kindergarten to 4th grade and a reading specialist certification. Abigail’s overall math identity score was 25, placing her in the lowest 12% of all participants. Throughout the interview, Abigail described herself as not being a strong mathematician, saying, “I don’t know that I’m necessarily an excellent mathematician” and “I think I am an excellent compensator!”

**Erin.** Erin is a seasoned teacher with over 26 years of experience teaching 2nd grade. In her mid-to-late forties, Erin often spoke of the differences between what she experienced as a math student and how she is expected to teach math today. Erin holds the old kindergarten through 6th grade Pennsylvania teaching certificate that is no longer available by the state. Erin’s overall math identity score was 25. Erin shared that she prefers the standard algorithm when solving math problems, saying, “I continue to do math using the standard algorithm” and “the way math is presented (today) makes me double guess myself as far as being good at math.”

**Ann.** Ann is a new teacher in her third year as an educator. Ann only has experience teaching 2nd grade and holds a pre-kindergarten through 4th grade Pennsylvania teaching certification. Ann was the only interview participant with an undergraduate degree as their
highest level of education (the other participants all have master’s degrees). Ann’s overall math identity score was 32, which puts her right at the mean for all participants in the study. Ann shared that her mathematical identity continues to develop, saying, “As I learn how to be a teacher in math, I think I’ve gotten better at math and understanding it.”

**Maria.** Maria is a veteran teacher with over 31 years of teaching experience. Over her career, Maria has taught 1st, 2nd, 3rd, and 4th grade mathematics. Currently, she teaches 4th-grade math to a population of students identified as academically gifted. During the interview, Maria referenced her experiences going to catholic school and her connection to her Italian heritage as having a significant influence on her life. Maria’s math identity score was 32, placing her right at the average for all participants in the study. Maria shared that she felt she “was not a math student” but “had to be willing and open to learning.”

**Evelyn.** Evelyn is in her sixth year of teaching math to 3rd, 4th, and 5th graders. She holds a pre-kindergarten through 4th grade and special education Pennsylvania teaching certification. In her mid to late twenties, Evelyn was very thoughtful with her responses and liked to connect her experiences as a student to the experiences that her students have today. Evelyn’s total math identity score of 38 falls in the top 17% of all participants. Evelyn describes that as a student, she was a “quiet perfectionist,” but now, as an adult, she feels like “you can be a flexible thinker in mathematics.”

**Iris.** Iris is in her mid-fifties and has over thirty years of teaching experience. In her thirty years as an educator, Iris has taught many grade levels and currently teaches 4th grade. With a total mathematical identity score of 41, Iris represents the top 8% of all study participants. As a student, Iris attended the same school where she currently teaches and often referenced the
changes that she has seen over the years. Iris shared, “I do feel that teaching has evolved in a really positive way.”

**Coding & Themes**

I used both inductive and deductive coding methods to analyze the data collected from the interviews. Specifically, I used an axial coding strategy to uncover categories during an initial inductive coding phase. Then, I connected the identified categories to broader themes deductively identified from the research questions. Axial coding is the process of relating categories to subcategories and is helpful when initial open coding requires additional structure and organization related to a research topic or phenomenon (Strauss & Corbin, 2003). This section will describe my coding process and the results from an inter-rater reliability analysis of my coding findings.

**Coding Results.** I used open coding for the initial inductive coding phase, which included reviewing each interview transcript and identifying key topics, phrases, or ideas the participants shared. Open coding provides context and allows general categories to emerge from the data (Saldaña, 2015). I reviewed each transcript twice, with the initial analysis identifying participants' key ideas and phrases. Then, I grouped these critical ideas into categories during the second review. After the initial coding phase, I identified seven shared categories among the participants. These categories included statements/ideas related to participants' math identity, experiences with past teachers, motivation for teaching math, beliefs about teaching math, experiences that shaped participants’ beliefs, communication with students, and beliefs about participants’ roles as math teachers.

Following the initial inductive coding, I used Stauss and Corbin’s (2003) axial coding method to identify key themes from my research questions that align with the initial coding
results. A hallmark of axial coding includes identifying key categories or themes around which the researcher can organize the subcategories (Strauss & Corbin, 2003). I identified four themes, three of which had two subcategories. The subcategories connected the categories identified during the initial open coding with the themes identified from the research questions. Table 4.10 shows the three qualitative research questions and associated themes and subcategories.

Table 4.10
Axial Coding Themes with Associated Research Questions

<table>
<thead>
<tr>
<th>Research Question</th>
<th>Identified Theme</th>
<th>Sub-Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>How are teachers’ mathematical identities influenced by their experiences as math students and educators?</td>
<td>Mathematical Identity Beliefs about past mathematical identity Beliefs about current mathematical identity Experiences as a student Experiences as an adult/professional</td>
<td></td>
</tr>
<tr>
<td>How do teachers’ mathematical identities align with their preferences for instructional choices?</td>
<td>Mathematical Identity Beliefs about past mathematical identity Beliefs about current mathematical identity</td>
<td>Preferred Teaching Strategies Experience with strategies as a student Beliefs about strategies as a teacher</td>
</tr>
<tr>
<td>What beliefs do teachers report about the importance of learning math, and how does this relate to the teachers’ mathematical identities?</td>
<td>Beliefs about Math Instruction</td>
<td></td>
</tr>
</tbody>
</table>

After using axial coding to identify the themes and subcategories, I returned to the transcripts and reorganized the identified categories into the five new themes. Each of the six participants had data included in the five themes, allowing for a comparative analysis of the themes based on each individual's identified mathematical identity value. The following sections present this analysis through the lens of each associated research question.

**Interrater Reliability.** To add reliability to the coding process, I partnered with a third-year doctoral student in the West Chester University of Pennsylvania’s Doctor of Education program. This individual is currently conducting a mixed methods study and is well-versed in inductive and deductive coding practices. I provided this individual with the list of identified themes, subcategories, and excerpts from the six transcripts totaling 15% of the collected data. After they completed an initial coding pass, we were 76.5% in agreement with the coding results. I then explained the five coding themes and their associated subcategories within the context of the study. After a second coding phase, we had 97% agreement on identified codes.

The difference between the initial and final coding process was mainly due to miscoding the subcategory *experiences with teaching strategies as a student* and the subcategory *past experiences as a student*. For example, one participant described their experiences with timed math fact fluency quizzes and how they thought they were ineffective. I coded this as an experience with teaching strategies as a student, while the other researcher coded it as an experience as a student. After explaining the study’s focus on participants’ perceptions of effective instructional strategies, we almost unanimously agreed. Following the inter-rater reliability check, I organized the themes to present them within the context of each research question.
Qualitative Analysis of Participants’ Mathematical Identities

Mathematical identity is a theme woven throughout this dissertation. During the quantitative analysis, I presented a measure of each participant’s mathematical identity, which I determined through the self-reported data from the initial survey. During the qualitative phase of the study, I investigated explanations for how the participants’ mathematical identities manifest through the context of forming beliefs about personal math abilities and beliefs about effective math instruction. To add validity and reliability to the quantitative measure of participants’ mathematical identities, I present a qualitative analysis of the interview participants’ mathematical identities through the lens of their self-reported accounts.

Participants describe their mathematical identities through self-reported beliefs and experiences during the interviews in qualitative data. Two subcategories emerged during the coding process related to participants’ mathematical identities. One centered on participants’ beliefs about their past mathematical identities, while the other subcategory related to participants’ current mathematical identities. Often, participants described their beliefs about their past mathematical identities and then compared them to their current beliefs about their mathematical abilities. I identified 61 excerpts from the transcripts relating to participants’ mathematical identities. Of the 61 excerpts, I coded 29 as describing participants’ past mathematical identities and 32 as manifestations of their current mathematical identities.

Participants’ Past Mathematical Identities. Exploring participants' past mathematical identities revealed common ideologies that they articulated during the interview process. There was little ambiguity in the participants’ responses except for one participant. Participants fell into two camps; either they remember themselves as strong math students or struggling math learners. For example, Abigail shared, “I felt that I was terrible growing up. I definitely did not feel strong
in math at all.” Maria described being a “plug and chug” math student who “struggled to apply anything she learned” outside of the specific lesson. Iris said she “was always comparing herself to her peers and feeling like she wasn’t very good at math.” In contrast, Erin and Evelyn talked about being strong math students, saying, “As a student, I did think I was good at math” and “I was really good at math.” Ann was the only participant who described feeling like an average math student, sharing, “I thought I was average. I wouldn’t say I thought I was really great.”

**Participants’ Current Mathematical Identities.** When reviewing the coded excerpts related to the participants’ current mathematical identities, the data reveals that participants hold strong internal beliefs about their abilities as mathematicians. Furthermore, the participants’ beliefs about their current math abilities aligned with the results of their determined math identity value from the quantitative analysis. For example, Erin and Abigail were in group A, representing participants with low math identity values. They believed they were still weak mathematicians, with Erin saying, “The way math is presented makes me double guess myself as being good at math.” Abigail shared, “I know that subtraction is not something that I’m good at, and I still use my fingers for certain things which drives me bananas.” However, Iris and Evelyn were in group C and had developed strong mathematical beliefs about their abilities. Evelyn described how, as an adult, she feels like she is “more creative and can think flexibly about numbers,” Iris exclaimed, “I am great at math!”

Furthermore, the two participants from group B shared comments suggesting that they feel like they are still developing their skills as mathematicians. Ann and Maria shared having both positive and negative beliefs about their abilities. For example, Ann said, “As I learned how to be a teacher in math, I think I’ve gotten better at math and understanding it.” Maria shared, “It obviously got easier as I grasped the math concepts better.” It is important to note that the
participants’ reflections on their past mathematical identities did not always align with their quantitative math identities determined from the survey. In contrast, the participants’ beliefs about their current math abilities aligned with the mathematical identities that I determined from the initial quantitative data.

**Research Question 3: Identity Shaped by Past Experiences**

Research shows that past experiences greatly influence individuals’ mathematical identities (Bray, 2011; Drake et al., 2001; Drake & Sherin, 2006; Stipek et al., 2001). I observed this phenomenon in the quantitative results through the distribution of the measured mathematical identity values and answers to the questionnaire items: *I enjoyed math class when I was in school, I believe that my math education was effective, and I was a good math student in school.* Quantitative results indicated a substantial variance in responses for each item, and participants reported having diverse opinions about their experiences as math students. Table 4.11 provides the variance and response counts for the three survey items related to participants’ past experiences.

In alignment with an explanatory sequential design, the quantitative results needed further investigation to explain the context for how participants’ past experiences influenced the development of their mathematical identities. This section examines the qualitative results of the research question: How are teachers’ mathematical identities influenced by their experiences as math students and educators?
Table 4.11

Quantitative Results for Items Related to Past Experiences

<table>
<thead>
<tr>
<th>Item</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>I enjoyed math class when I was in school.</td>
<td>4</td>
<td>16</td>
<td>3</td>
<td>10</td>
<td>15</td>
<td>2.057</td>
</tr>
<tr>
<td>I believe that my math education was effective.</td>
<td>3</td>
<td>10</td>
<td>8</td>
<td>19</td>
<td>7</td>
<td>1.366</td>
</tr>
<tr>
<td>I was a good math student in school.</td>
<td>2</td>
<td>6</td>
<td>8</td>
<td>17</td>
<td>15</td>
<td>1.329</td>
</tr>
</tbody>
</table>

*Note: Data comes from self-reported responses from the initial survey.*

**The Theme of Past Experiences.** Coding revealed two subcategories related to past experiences shaping mathematical identities. The first subcategory included excerpts describing participants' *experiences as a student*, while the second subcategory identified participants’ *experiences as adults/professionals*. For clarification, I coded all descriptions of experiences in college as *adult/professional*. I chose this because participants described their college experiences from classes where they learned how to teach math rather than a class focused on learning math content. This distinction is important because the participants who shared their college experiences did so in connection to other professional development experiences. Furthermore, I coded any experiences participants shared about students they taught or with their children as *adult/professional experiences*. In total, 45 excerpts were coded using the past experiences theme, with 28 relating to *past experiences as a student* and 22 identified as *adult/professional experiences*.
Participants’ Past Experiences as Students. Analyzing the data coded for past experiences as a student revealed that each participant shared memories they had as a math student that greatly influenced the development of their mathematical identity. Participants often shared memories of their past teachers. They all described these memories as positive experiences, highlighting supportive teachers who made them feel safe and who established a positive relationship with them in the classroom. Abigail said, “I had an excellent third-grade math teacher. Everybody felt like they had a relationship with her.” Maria shared, “I was very blessed. I went to an extremely great elementary school, and those teachers are the ones who made me want to become a teacher.”

The coding revealed that participants often shared general characteristics and experiences that they remembered instead of specific one-time events when describing these positive events. For example, Evelyn talked about a teacher who would “always praise her for her effort,” and Iris shared a story about a middle school teacher who “made her feel like it was ok to make mistakes.” Abigail spoke about a teacher who worked with her one-on-one throughout the year and helped her overcome her math anxiety. Ann shared, “I feel like I had really great teachers,” and Maria made a connection with a teacher because “she was Italian, and so I wanted to make her happy by doing well” in math. In each of these cases, the participants did not describe one particular memory but shared the traits of their teachers that positively impacted their development as math students.

In contrast, when the participants shared memories of the classroom experiences that shaped their mathematical identities, they often referenced specific in-the-moment experiences they had as math students. For many of these memories, the participants described situations that evoked a negative experience, personal struggle, or high anxiety situation. Participants described
these memories in detail and often referenced how they still think about these experiences today. Table 4.12 provides excerpts of specific classroom memories shared by participants that they identified as having a significant impact on the development of their mathematical identity.

### Table 4.12

**Participants’ Classroom Experiences as Math Students**

<table>
<thead>
<tr>
<th>Participant</th>
<th>Classroom Experience as a Student</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abigail</td>
<td>“I have a very strong memory of hiding under a table in first grade and like sobbing while I was doing math. I was just terrible at it.”</td>
</tr>
<tr>
<td>Ann</td>
<td>“In fifth grade we were learning long division, and I remember something about a cloud number. You had to do something with the cloud number, and I remember being so confused.”</td>
</tr>
<tr>
<td></td>
<td>“I remember in honors trigonometry, the homework would have something new and I would have to ask the Priest to go over it again and show me how he solved the problem. I was not a math student.”</td>
</tr>
<tr>
<td>Maria</td>
<td>“I remember sitting in class and doing these problems in these orange math books. The teacher would walk around and give you a little check or a check plus, depending on how you answered the problems.”</td>
</tr>
<tr>
<td>Evelyn</td>
<td>“I cheated in math. I remember it profoundly that I never learned long division because I copied off of people beside me. I remember having to go to the board to do races and the fear of having to perform in front of my peers. It is seared in my memory.”</td>
</tr>
</tbody>
</table>

*Note: Some of these responses combine excerpts from the interviews as participants referenced the same experience multiple times.*

**Participants’ Past Experiences as Adults/Professionals.** When reflecting on the experiences that shaped their mathematical identities, participants also referenced memories from college, as professionals, and with their children. These excerpts, coded as *adult/professional experiences*, revealed that some participants experienced a transition in their
mathematical identity while others reaffirmed their established beliefs. The results indicate that participants with a lower mathematical identity described experiences reaffirming their beliefs. In contrast, those with higher beliefs in their math skills described experiences that changed their perspective of their mathematical identities.

From group A, participants with lower mathematical identity scores, Abigail and Erin described experiences that reaffirmed their established beliefs. Abigail shared, “I definitely know where my weaknesses are, and I can point to them. So, when I teach, I work hard to identify very specific strategies for my students so that they don’t fall into the same loopholes.” Erin described, “When my eighth-grade son asks me things, I don’t know how to do it. I go onto those websites where you can find the answers.” In both examples, Abigail and Erin describe experiences where they were trying to overcome their own perceived shortcomings as mathematicians.

In contrast, Iris and Evelyn, from group C with high math identity values, shared experiences that changed their thinking about math abilities. Evelyn shared the importance of experiences with her colleagues, saying, “It wasn’t until I met some colleagues here at my current workplace that I actually became excited because I realized that you could be creative in math.” In addition, Iris and Evelyn referred to their college experiences as pivotal in shaping their mathematical identity. Iris shared, “At the college level, I think for the first time I heard that I was good at math and that maybe I should consider becoming a math teacher, and that changed everything.” Evelyn said, “Then when I went to college and explored math where there wasn’t a pressure, and I felt like the teacher wasn’t judging me, it helped me gain more confidence and think flexibility.” The experiences Iris and Evelyn shared represent moments when they thought about math in new ways that excited them and changed their viewpoints and beliefs.
Maria from group B also shared experiences with her children that influenced her mathematical identity. Maria described that her son was gifted and would get frustrated with excessive math problems each night. Maria said, “His (son's) gifted math teacher gave him 30 long division math problems a night. 30! Not 5, not 10, and he already showed mastery, so he would get frustrated.” She explained, “Seeing how my own children were being delivered math, I questioned its authenticity.” Maria explained that these experiences shaped her belief that students can have more control over their learning and that teachers should be “ready for creative problem solvers because there are different ways to do math.”

Connection Between Math Identity and Experiences. Investigating how past experiences shape individuals' mathematical identities uncovered intricate connections between personal history and present perceptions. It is evident that participants’ positive and negative classroom experiences as students left lasting impressions. Furthermore, participants' experiences as adults and professionals, whether reaffirming existing beliefs or prompting a shift in perspective, demonstrate the dynamic nature of mathematical identity development. I present a further discussion of the implications of these results in Chapter 5.

Research Question 4: Identity and Teaching Strategies

A link exists between teachers’ mathematical identities and their preference for different teaching strategies. Research has shown that teachers with a more negative mathematical identity tend to hold more traditional beliefs, emphasizing student computational skills, algorithmic thinking, teacher-centered instruction, and getting the correct answer (Stipek et al., 2001). Additionally, teachers who have experienced problem-based collaborative math instruction are more likely to value teaching strategies that promote dialogue, collaboration, and productive struggle (Boaler, 2015; Boaler & Staples, 2008).
In the quantitative analysis, I explored this phenomenon through the survey items: *I believe that solving math problems quickly is important, I like to teach using the same strategies that I was exposed to as a math student, I prefer instructional strategies that maximize collaborative problem solving, I believe that students learn best when they engage in discussions about problem-solving, and I believe that feedback on how students engage with math problems that is not centered on the final answer is valuable.* The quantitative results indicate general agreement among participants regarding their beliefs about problem-based instructional strategies and teacher feedback's role in supporting student learning. 85.7% of participants indicated that they prefer strategies that maximize collaborative problem-solving. In addition, 84% of participants believe that students learn best when they engage in discussions about problem-solving and that teacher feedback on how students engage with math is valuable.

However, I observed increased variance when participants responded to the items about valuing the ability to solve math problems quickly and their preference to teach using the same strategies they were exposed to as math students. Table 4.13 provides the variance and response counts for these two survey items. The observed variance in these items requires further investigation to explain the context for how participants’ math identities influence their preferred math teaching strategies. This section examines the qualitative results of the research question: How do teachers’ mathematical identities align with their preferences for instructional choices? It is important to note that the data presented for participants’ preferred teaching strategies comes from self-reported accounts provided during the initial survey and interviews.
Table 4.13

Quantitative Results for Items Related to Preferred Teaching Strategies

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>I believe that solving math problems quickly is important.</td>
<td>3</td>
<td>9</td>
<td>7</td>
<td>16</td>
<td>13</td>
<td>1.570</td>
</tr>
<tr>
<td>I like to teach using the same strategies that I was exposed to as a math student.</td>
<td>6</td>
<td>11</td>
<td>13</td>
<td>12</td>
<td>6</td>
<td>1.510</td>
</tr>
</tbody>
</table>

Note: Data came from self-reported responses from the initial survey.

**The Theme of Preferred Teaching Strategies.** Coding the interview transcripts revealed two subcategories related to preferred teaching strategies. The first subcategory included excerpts describing participants' experiences with instructional strategies as a student, while the second subcategory identified participants’ beliefs about instructional strategies as a teacher. During the interviews, I asked participants to describe teaching strategies they remembered their elementary teachers using in math class. I asked them to share if they thought these strategies were effective. I also asked participants to share their experiences with math as students compared to how they teach math as educators. Finally, I asked participants what teaching strategies they believed were the most effective in their classroom. I coded 22 excerpts using the subcategory, experiences with instructional strategies as a student, and 41 excerpts in the subcategory; beliefs about instructional strategies as a teacher.
Participants’ Experiences with Teaching Strategies as a Student. The qualitative analysis revealed a common theme among the participants regarding their experiences as elementary math students. Participants shared memories of their teachers focusing on math facts and the standard algorithm/steps to solve problems. Participants shared that there was a focus on memorization and practice. Given the age ranges of the participants, it is important to recognize that their experiences occurred between the late 1970s through the mid-2000s. Table 4.14 provides excerpts from each participant about their recollection of math strategies focused on procedures, memorization, and practice.

Participants identified additional unique teaching strategies that they experienced as elementary math students. Erin and Evelyn remembered how their math classes were teacher-centered, and they commonly experienced whole-group instruction. Erin said, “Everything was taught whole group,” and Evelyn shared, “I remember a lot of whole-group where she modeled problems for us, and then we had to go back to our seats and work in a workbook.” Erin also shared a lack of math tools, saying, “manipulatives and things weren’t used as much.” Ann talked about the lack of focus on understanding math concepts she experienced as a math student, saying, “It was less about understanding the why with math,” Finally, Iris shared her experience with teachers doing speed practice games in front of the class. Iris shared:

There was a lot of going to the board and write, and six people lined up at the board with a problem, and it was a race. There were relays heading to the board where you do the next step of a problem. I remember a fear of having to perform in front of my peers.

The excerpts shared in this section illustrate the overwhelming number of experiences participants had learning math that are considered traditional practices today and which are associated with a more negative or lower mathematical identity.
Table 4.14

Participants’ Memories of How Math was Taught as Elementary Students

<table>
<thead>
<tr>
<th>Participant</th>
<th>Memories of Elementary Math Instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abigail</td>
<td>“My school growing up would do speed drills. My teacher would email my parents and say I didn’t know my math facts at all. I would sit there for 15 minutes every night doing math fact practice.”</td>
</tr>
<tr>
<td>Erin</td>
<td>“I just felt like in elementary school, we spent most of the time doing simple computations and things that I could learn fairly quickly by heart. I remember everything was standard algorithm.”</td>
</tr>
<tr>
<td>Ann</td>
<td>“I remember it was less about understanding the why with math and more here’s how you do it, practice it, and then memorize it and know it. We learned a lot of standard algorithms.”</td>
</tr>
<tr>
<td>Maria</td>
<td>“I don’t think any of them [teachers] had any specific strategies other than showing us, writing it on the board, and walking us through the steps. We maybe had 5 or 10 problems to do each night. They may have been like copy these problems; we want you to practice them to show the proper way to solve.”</td>
</tr>
<tr>
<td>Evelyn</td>
<td>“The teacher would show the steps to solving a problem and then repeating those steps and solving. I solved the math problems the way the math teacher solved it and I went home and I solved it the same way.”</td>
</tr>
<tr>
<td>Iris</td>
<td>“It was a lot of rote. It was a lot of the standard algorithm of math. Math was very proceduralized, and a lot of just doing pages and pages of practice. It was just computation heavy.”</td>
</tr>
</tbody>
</table>

Note: Some of these responses combine excerpts from the interviews as participants referenced the same experience multiple times.
Participants’ Beliefs about Effective Teaching Strategies. Diving deeper into the participants’ experiences as students reveals that not all participants believe that the practices used by their elementary teachers were ineffective. The participants with a lower mathematical identity value shared beliefs that they prefer teaching the algorithm, mastering math facts, and teacher-centered instruction. In contrast, the participants with the highest math identity values shared their classroom preferences that encourage discourse, authentic and purposeful feedback and are student-centered. In this section, I present the findings from asking participants which instructional strategies they prefer to use as math teachers.

Group A’s Beliefs about Effective Math Instructional Strategies. The group A participants, Erin and Abigail, shared how they like to run their math classes. As they spoke, frustrations about how they are expected to teach math and how they like to support struggling learners in their classrooms emerged from the conversation. Qualitative evidence exists that Erin and Abigail are trying to embrace more open problem-solving math instruction but are struggling to believe in its effectiveness.

Abigail is proud that her students call her the question lady. She explained, “I have been dubbed the question lady, so I try to ask my kids as many questions as possible. I try to provoke some sort of conversation.” She references questions such as “Why do you think that and How would you explain that?” Abigail has embraced the importance of dialogue and questioning in her math classroom. However, Abigail also shared beliefs that suggest her focus remains on math facts and teaching the standard algorithm. Abigail said, “I work hard to get my kids to see if you’re good at multiplication, but you’re not good at division, or good at addition but not good at subtraction; here are some ways that you can flip it.” This excerpt demonstrates Abigail’s reliance on tricks to make math more accessible for her students so that they can experience
success. Furthermore, Abigail shared that “the number one issue with math is not knowing your math facts.” It is important to share that Abigail cares deeply for her students and believes the most essential strategy she can use as a teacher is building positive relationships with students and making them feel safe.

Erin shared that she believes in teaching math in a way that provides students with options and choices to demonstrate what they know. Erin said, “I don’t feel like I push certain ways on the kids. I always give them choices, and that makes the most sense.” However, Erin also shared strong negative opinions about problem-based math learning programs that promote more flexible thinking. For example, Erin shared:

Even though it’s not in the manual, I taught the standard algorithm because I feel like you’re not going to be getting your base ten blocks and your hundreds chart out at the supermarket when you need to do these types of things.

Erin also explained, “Using a number line, which is a big push in this math series, I don’t like it. Personally, I just don’t feel like you’re ever gonna get out a number line.” Furthermore, when Erin supports struggling students, she believes that teaching the standard algorithm is the best approach to help them learn math. Erin shared, “For lower-level kids, it can be challenging; I often just give them, you know, this is what you’re good at. This is the strategy you should use.” Erin also prefers to provide math instruction in small groups based on student ability levels. I asked Erin if she does a lot of direct instruction or more collaborative problem-solving with her small groups, and she responded by saying, “It’s pretty much teacher-directed. Again, I’m working with lower-level students.” These excerpts demonstrate that Erin’s mathematical identity manifests in her preferred instructional strategies.
Group B’s Beliefs about Effective Math Instructional Strategies. Ann and Maria, representing participants with an average mathematical identity, share beliefs incorporating traditional and a more progressive approach to teaching math. Ann shares beliefs that prefer a more traditional method of instruction, while Maria prefers strategies often associated with a more positive mathematical identity.

Ann explains how she values strategies that allow students to show what they know without the high stakes associated with tests. Ann says, “I don’t even call the assessments tests; I call them show what you know, and I tell them that it is all about doing your best.” However, Ann believes that their new program is challenging for the students, and when she sees them struggle, she prefers to teach them a strategy that she knows will work. Ann describes her situation:

Our curriculum really dives into the why of math and what goes behind it. Sometimes, I see that it’s just too much for my students. So I go, ok, well, if you do it this way, this is why, but this is the way to do it.

Ann expands on this belief by discussing helping struggling students in small groups. She shared:

I’ll find myself doing a lot more of what my teachers used to do or how I learned math best when I notice that they [students] need those more specific interventions. With the whole class, it is more of what I’m expected to do and the way the curriculum works.

Ann’s accounts demonstrate how she reverts to her comfortable beliefs about effective instructional strategies when her students experience challenges and struggles.

Maria’s instructional preferences center around establishing a student-centered classroom that promotes conceptual understanding. She said she “disagrees with any teacher who thinks
they have to give students the answer or even show them how because they’re not going to learn from that.” Maria believes that effective teaching strategies include students “explaining their thinking first, and then you work beside them. Have students check the information and show their process of thinking. I think it really is the best strategy when working with kids.” Maria explains that she likes to ask students questions that prob their thinking. For example, she says, “Show me your thinking; write down what you're thinking.” Maria’s instructional preferences align with changes promoted by the mathematical reform movement (NCTM, 2018) and represent a teacher comfortable with flexible and creative thinking in a math classroom.

*Group C’s Beliefs about Effective Math Instructional Strategies.* The interviews with Iris and Evelyn revealed a strong preference for instructional strategies that encourage student-centered, flexible thinking and discourse in the math classroom. Promoting a student-centered classroom was articulated in multiple excerpts from both participants. Iris explained, “Even when we were with a math program that didn’t have that [collaborative] structure, I still did just discourse heavy and discussion heavy, with no fear and no shame.” Later in the interview, Iris added, “I do a lot of total participation strategies.” Evelyn also preferred student-centered strategies. She described, “Communication is most important and what I value in my math classroom. I use [the strategy of] think, pair, share, student talk, and partner work. Myself modeling is last. Letting the kids do the thinking first is important.” Both Evelyn and Iris describe teaching strategies that require the students to think first and the teacher to help guide the students through the process of understanding.

Additionally, Iris and Evelyn described strategies that provide constructive and purposeful feedback to students as instructional techniques they prefer. Evelyn said, “I try to be intentional with my feedback and push them [students] forward with a goal in mind.” Iris shared,
“During learning, there’s a lot of feedback. Students are in whole group partners or independent triads and then come back together. That way, they are constantly in front of an adult, or if they’re in front of a peer, I’m twirling.” Iris and Evelyn’s value of effective feedback demonstrates their understanding of the importance of being responsive in a student-centered classroom.

**Connection Between Math Identity and Preferred Instructional Strategies.** The qualitative analysis of participants’ beliefs about effective teaching strategies in relation to their mathematical identities reveals distinct differences between the mathematical identity groups. Group A participants, representing those with the lowest mathematical identities, preferred more traditional, teacher-centered instructional approaches. In contrast, Group C participants, with the highest mathematical identity values, preferred student-centered, discourse-rich instructional strategies. An excerpt from Iris’s interview describes the evolution of teachers’ preferred strategies for teaching math as they develop a more positive mathematical identity:

As opposed to years ago, when I would see a group at the back table and, there’d be 2 or 3 other groups kind of sitting on their own, struggling and trying to get through the problems. I might have thought they were fine, so they didn’t need to be at the table with me. Some of those kids were not fine. They were the Me, when I was younger, sitting there like, maybe I can look off this other person’s paper. Now, at the grade level I’m at, I really feel the discourse, the conversation, the talking it through, the sharing strategies, the providing alternate paths, and the philosophy that there are many ways to get there is key.”

I present a further discussion about the influence that mathematical identity has on preferred teaching strategies in Chapter 5.
Research Question 5: Participants’ Beliefs about the Importance of Learning Math

Research shows that teachers may struggle to adopt more progressive ideologies about the importance of learning math primarily because they experienced more traditional mathematics instruction as students and, therefore, do not believe in a constructivist approach to math education (Boaler & Staples, 2008; Bray, 2011; & Wilkins, 2008). To investigate this phenomenon, I included four items in the survey that asked participants to share their beliefs about why they think it is important to learn math. The survey items were: I believe that it is important that people are able to explain their reasoning in math; I believe that people see value in what they learn in math class; I believe that the concepts people learn in math class are vital to their success in life, and I believe that it is my responsibility to build my students’ beliefs that they are good at math.

The quantitative results indicate strong agreement among participants regarding each survey item. Over 80% of participants indicated that they agreed with each of the statements. For the item, I believe that it is my responsibility to build my students’ beliefs that they are good at math; 100% of participants agreed, and 75% strongly agreed. In addition, 89.6% of participants reported that they believed that the concepts people learn in math are vital to their success in life.

Given the lack of variance and general agreement reported on the survey, the quantitative data suggests that there is no relationship between the participants’ mathematical identities and their beliefs about the importance of learning mathematics. Furthermore, the quantitative data indicates that the participants value more progressive math beliefs, including the importance of students being able to explain their answers, fostering a growth mindset, and connecting math instruction to real-world application. However, an individual’s beliefs are nuanced and require additional explanation to understand participants’ perspectives and values. In this section, I
present the qualitative data that provides greater insight into participants' self-reported beliefs about the importance of math instruction to answer the research question: What beliefs do teachers report about the importance of learning math, and how does this relate to the teachers’ mathematical identities?

**The Theme of Beliefs about the Importance of Math Instruction.** After analyzing the transcripts, I coded 45 passages relating to participants’ beliefs about the importance of learning mathematics. Unlike the quantitative results, the qualitative data suggests that participants with a lower mathematical identity score believed that mathematical success and focusing on the outcomes of solving math problems is the most important. Compared to group A, the participants with higher math identity scores shared their belief that building flexible thinkers who collaborate, persevere in the face of productive struggle, and construct a growth mindset is most important in their math classroom.

**Defining Student Success.** The participants often shared their beliefs about the purpose of learning math. Distinct differences related to the participants’ mathematical identities emerged as the teachers described their beliefs. Erin and Abigail, who were both in the lower math identity value group, referenced the importance of students feeling and achieving success as defined by being able to solve problems and apply math strategies that work. Erin shared, “I think introducing them [students] to a million different strategies and actually testing them on strategies is silly. The ultimate goal is can they subtract and regroup and get the right answer.” Erin referenced the goal of getting the correct answer three times during her interview, with her last comment being, “The ultimate goal is, can you solve the problem.” Like Erin, Abigail also believes in goal-oriented math instruction, which defines success as students solving math problems. Abigail shared, “Here’s a whole mess of different ways for you to teach the same
concept. The goal is that you are looking for the one that’s gonna fit for each kid.” Abigail also shared that she felt it is important for students to know if they are successful in math. She said, “I feel like kids are and should be held accountable for their learning.” Erin and Abigail’s excerpts demonstrate that they believe it is important for teachers to support students in successfully solving math problems.

Maria and Ann from group B, participants with an average math identity value, also spoke of the importance of supporting student success in math class. However, Ann and Maria apply a broader understanding of student success. Ann shared that she believes making sure students know the purpose and why behind their math work is critical. “I always try to teach my kids, here’s the purpose, here’s why we’re doing this. Okay, now you have a purpose.” However, Ann also shared, “We do all this stuff to try to get the kids to understand the background, and sometimes what they need is they need to know how to do it first, and then the why can come after that.” Ann’s responses illuminate her beliefs that explaining the why and purpose are important, but she also values students’ ability to solve problems successfully. Maria also describes a purpose beyond basic computation still rooted in successful problem-solving. Maria shared, “My goal is to say, okay, you already know how to solve this type of problem; now apply it to a new situation.” Maria believes it is important for students to be flexible with their knowledge, but she still expects students to successfully apply their knowledge by solving higher-depth problems.

Group C participants Iris and Evelyn shared beliefs that focused much more on developing skills that support open problem solving, such as flexibility, collaboration, and perseverance during productive struggle. Iris explained, “A huge mantra in our class is that mistakes are where the learning takes place, not something to hide from.” Iris shared that over
time, “I learned number one that you didn’t have to be perfect.” I asked Iris what she thinks maximizes her students’ abilities, and she shared, “Giving everyone an entry into every problem, giving everyone an entry into all the strategies, and then giving the choice to choose what works best for them.” In concert with Iris, Evelyn also shared beliefs that flexibility and collaboration are important for student success in the math classroom. She said, “I understand the importance of thinking flexibly with the numbers. So now, I value that as a mathematician.” Evelyn also shared, “Now it’s all about communication. They [students] get to communicate every day about numbers.” In both examples, it is evident that Iris and Evelyn believe that student success in math is focused more on how they engage in problem-solving and the development of skills that support collaboration and perseverance.

**Participants’ Beliefs about Fostering a Growth Mindset.** It is worth noting that Iris, Evelyn, Maria, and Ann also shared their beliefs on the importance of fostering a growth mindset with their students. Maria shared, “I do think, as a teacher, you have to have a willingness and an openness to say, I don’t know what I did, and I can learn, and you can learn it [as well].” Ann said, “Write a positive note like I noticed how hard you worked. If I see a lot of eraser marks, I notice how hard you worked.” Maria and Ann shared how they foster a growth mindset in their students and believe that keeping students believing in themselves is important to their success. Evelyn and Iris shared their beliefs about their role as teachers in supporting a growth mindset. Evelyn said, “I focus so much on that growth mindset first. Because I could see how that could get in the way of somebody’s understanding because it happened to me firsthand.” Iris shared, “It all depends on really building a culture in the classroom. A culture where kids can make mistakes. We build the capacity that they’re not embarrassed to share what they did wrong
because that’s where the learning is happening.” The qualitative analysis did not reveal any reference to the importance of fostering a growth mindset from Erin or Abigail.

**Connection Between Math Identity and Beliefs about the Importance of Math.** The qualitative analysis of participants' beliefs about the importance of learning mathematics provided valuable insights into the relationship between their mathematical identities and instructional perspectives. Participants with lower mathematical identity scores tended to prioritize traditional mathematics success measures that value accuracy and solving. They emphasized the ability to solve problems and apply specific strategies. In contrast, participants with higher mathematical identity scores stress the importance of fostering flexible thinking, collaboration, and perseverance during problem-solving. In Chapter 5, I provide a further discussion of this phenomenon.

**Overarching Research Question**

This explanatory sequential mixed-methods study aims to investigate the manifestation of elementary teachers’ mathematical identities through participants’ perceptions of effective math instruction. The overarching research question that supports this purpose is: How does an elementary teacher’s mathematical identity affect their self-reported beliefs about effective math instruction? The overarching research question requires further discussion that combines findings from each subsequent research question. As a result, I will present a detailed discussion of the findings related to the overarching research question in Chapter 5.

However, I asked each participant if they would prefer to repeat their math experience growing up or be a student in today’s math class. As participants answered this question, they shared perspectives representing their summative beliefs about math instruction. From the responses to my question, I identified the excerpts from each participant that provide perspective
about their beliefs about effective math instruction. Table 4.15 provides excerpts related to the participants’ self-reported beliefs about effective math instruction in response to my question.

**Table 4.15**

*Participants’ Self-Reported Beliefs about Effective Math Instruction*

<table>
<thead>
<tr>
<th>Participant</th>
<th>Memories of Elementary Math Instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abigail</td>
<td>“I think I am an excellent compensator. I definitely wonder if I would have been in like a math intervention group. I think there’s like knowing the evil versus not knowing the evil. I know myself, so would the multiple strategies be overwhelming to me, or was it better that I was only taught one way?”</td>
</tr>
<tr>
<td>Erin</td>
<td>“It would be okay to have a little of the old and a little of the new. I like exposing the kids to all these strategies. The ultimate goal is, can you solve the problem? I also think there’s confidence [in students]; you know, they’re not scared.”</td>
</tr>
<tr>
<td>Ann</td>
<td>“I don’t know; I really think I’d like to repeat my experience. As much as I enjoy teaching math, I think that I couldn’t learn 14 different strategies.”</td>
</tr>
<tr>
<td>Maria</td>
<td>“Oh, gosh! Repeat the experience growing up! I feel like we are giving kids too much. We’re choking them; we are choking our children. We’re giving them expectations that are so much at such a fast pace that I don’t think they even have changes to absorb it.”</td>
</tr>
<tr>
<td>Evelyn</td>
<td>“I would prefer to be a student in today’s math class. I think my math identity would have been a little more positive if I had the confidence and time to communicate with my peers around math. They’re [students] lucky.”</td>
</tr>
<tr>
<td>Iris</td>
<td>“I would rather be a student here. A million times over, and if I didn’t, I shouldn’t be here in front of the class. What my students are learning now is heads and shoulders above what they were learning just ten years ago. They are learning more, and it is a deeper understanding.”</td>
</tr>
</tbody>
</table>

*Note:* The information in this table came from responses to the question: Would you prefer to repeat your experience learning math or be a student in today’s math classroom?
Summary

In Chapter 4, I presented the results of the mixed-methods study investigating the relationship between elementary teachers' mathematical identities and their beliefs about math instruction. This chapter detailed the study's methodology, sample overview, and findings from both quantitative and qualitative analyses.

The quantitative analysis examined educators' self-reported responses to the initial survey and evaluated possible relationships between participants’ identities and demographic factors. The data revealed diverse mathematical identities among participants that were normally distributed. This suggested varied instructional beliefs and practices which required additional explanation. The qualitative research explored how teachers' past experiences as students and educators shaped their current mathematical identities and influenced their beliefs about instructional preferences. The data highlighted that participants’ mathematical identities significantly impact teachers' beliefs about effective math instruction. Chapter 5 will offer a deeper discussion of each research question, aiming to contextualize the implications of teachers' mathematical identities for effective math instruction.
Chapter 5

This explanatory sequential mixed-methods study aimed to investigate the manifestation of elementary teachers’ mathematical identities through their self-reported beliefs about effective math instruction. Students start to experience challenges in mathematics at the elementary level (PA Department of Education, 2022; NCTM, 220a), and efforts to improve mathematics instruction have yet to significantly improve student achievement (Desliver, 2017; NCTM, 2018). In light of these ongoing challenges, researchers seek to understand how mathematical identities may influence teachers’ ability to unlock students’ mathematical potential and produce higher-achieving mathematicians. This study aimed to explain better the connection between teachers’ mathematical identities and their self-reported beliefs about math instruction.

For this research, I focused on how teachers formed their mathematical identities and then explained the participants’ identities’ impact on their reported beliefs about effective teaching strategies and the purpose of teaching mathematics to students. I used quantitative data to identify the participants’ mathematical identities and explore potential relationships between their identities and demographic data. Then, qualitative data was collected to explain the context and details and add insights into the initial findings.

In this chapter, I summarize the findings for each research question and present a discussion that connects the study's findings to existing research. I present these findings and discussion in three sections: the quantitative and qualitative results and an analysis of the overarching research question: How does an elementary teacher’s mathematical identity affect their self-reported beliefs about effective math instruction? I then draw connections between the quantitative and qualitative findings of the study and my theoretical framework. I end the chapter
Discussion of Quantitative Findings

The quantitative findings resulted from analyzing the data from the initial survey, in which I collected 48 valid responses. In this section, I discuss the results of the two quantitative research questions: *What percent of educators surveyed report developing a positive versus negative mathematical identity*, and *Is there a relationship between the reported demographics of teachers and their self-identified mathematical identities?* For each question I provide a brief overview of the findings and a discussion of the interpretation of the data connected to the literature.

Discussion of Research Question 1: Participants' Mathematical Identities

The quantitative analysis of the survey data provided interesting insights into the development and manifestation of elementary teachers’ mathematical identities. By creating a Likert scale data set, I determined that participating teachers’ mathematical identities existed along a normal distribution. Therefore, I could compare the teachers’ identity values along a continuous data set. As a result, I found that 18.8% of the participants had a mathematical identity greater than one standard deviation from the mean, and 18.8% had an identity value less than one standard deviation from the mean. This result aligns with research suggesting that the formation of mathematical identities is individual and develops through in-the-moment encounters and over long periods (Darragh, 2016; Gee, 2000).

Although I determined that participants held unique mathematical identities, the individual survey items revealed the complexity of understanding how teachers’ mathematical identities manifest in practice. For example, the near-unanimous agreement among participants
on the usefulness of mathematics in daily life and their enjoyment and confidence in teaching mathematics reveals a positive perspective toward math among educators. This result contrasts the varied responses recorded about the importance of speed and accuracy in solving math problems. The findings indicate that the participants may compartmentalize their beliefs into different contexts, including perceptions of their roles as a teacher and opinions on the ultimate goals of math instruction.

Participants’ responses to the survey questions about student math abilities and effective instructional practices further revealed mathematical identities' dynamic and complex nature. Significant variance existed in participants’ opinions about whether or not certain students are inherently better at math and are born with math brains. In contrast, the universal agreement among participants that teachers are responsible for building students’ confidence in math and should provide feedback beyond correctness highlights the collective belief in fostering problem-solving skills. The participants’ responses to these questions indicate beliefs that align with the mathematical reform movement’s emphasis on nurturing positive mindsets in students (NCTM, 2018).

In summary, the data revealed that different mathematical identities exist among the participants and manifest as dynamic beliefs unique to each participant. The complex nuances associated with studying the participants’ mathematical identities align with Campbell et al.’s (2014) findings, suggesting that a teacher’s beliefs/perceptions differ from teacher knowledge in that beliefs/perceptions are not verifiable or based on facts but rather individual construction and interpretation. Furthermore, Wood’s (2013) findings agree that mathematical identities are dynamic and can change in the moment as they become more concrete over time. As a result, the quantitative analysis fails to adequately explain the manifestation of the participants’
mathematical identities without further investigating the meaning and context of their self-reported survey responses.

**Discussion of Research Question 2: Relationship between Demographics and Math Identity**

To further investigate possible factors that influence the development of an individual’s mathematical identity, I analyzed the relationship between participants’ demographic data and their measured mathematical identities. Research has found that women and teachers who experience more traditional math education tend to develop more negative or fixed mathematical identities (Boaler & Selling, 2017). This finding suggests that older participants with more teaching experience are likelier to exhibit a lower mathematical identity value. I conducted the analysis using the hypothesis that a relationship does exist between demographic variables and the participants’ measured mathematical identities. Following quantitative methodology, I sought to reject the null hypothesis that a relationship does not exist between participants’ demographic data and their mathematical identities.

I investigated this phenomenon through one-way-between-groups analysis of variance (ANOVA) tests to determine if a statistically significant relationship exists between the participants’ mathematical identity values and their gender, age, years of teaching experience, the highest level of education they received, and grade level they are teaching. I could not analyze gender because I did not have enough participants who identified as non-female (n=4). For each of the remaining demographic variables, the ANOVA analysis revealed that no statistically significant relationship existed among the participants. As a result, the null hypothesis was not rejected.

Although I was surprised that I found no relationships between the demographic variables and the measured mathematical identity values of the participants, the results continue to align
with research that recognizes the complex nature of studying mathematical identity (Brown, 1996; Sfard & Prusak, 2005). Because lived experiences influence the construction of mathematical identities, it is unlikely that any demographic data point would show a significant relationship with the overall construction of the participants’ beliefs. The results of this quantitative analysis continue to support the need for further explanation of the development and manifestation of the varied participants’ identities.

**Connecting the Quantitative Discussion to the Theoretical Framework**

The quantitative analysis of participants' mathematical identities and the theoretical framework offers valuable insights into how teachers' beliefs and experiences shape their perceptions of math instruction. This section discusses the findings within Vygotsky's sociocultural theory of learning and Sfard and Prusak’s mathematical identity theory while recognizing the complex interactions between personal experiences, beliefs, and instructional practices.

**Vygotsky’s Sociocultural Theory of Learning**

Vygotsky’s theory suggests that individuals construct knowledge through social interactions and cultural contexts (John-Steiner & Mahn, 1996). The quantitative analysis of teachers' mathematical identities reflects the influence of their educational experiences and social interactions on their beliefs about mathematics. The findings suggest that teachers' confidence in their mathematical abilities and beliefs about effective instruction are integrated with their past experiences as students and educators. For instance, the strong agreement among participants regarding the usefulness of mathematics in daily life supports Vygotsky's emphasis on the practical application of knowledge acquired through social interactions.
Sfard & Prusak’s Mathematical Identity Theory

Sfard and Prusak's (2005) theory suggests that individuals construct mathematical identities over time through lived experiences and social interactions. This quantitative analysis supports this idea by revealing the dynamic nature of participants' mathematical identities. While some participants exhibited positive mathematical identities characterized by confidence and interest in mathematics, others displayed more negative or fixed identities, emphasizing the importance of getting the correct answer. This diversity in observed mathematical identities brings to light the complex nature of identity construction and its impact on teachers' instructional beliefs and practices.

Analysis within the Theoretical Framework

By analyzing the quantitative data through the lens of Vygotsky's sociocultural theory and Sfard and Prusak’s mathematical identity theory, the study clarifies how teachers' sociocultural contexts and personal experiences shape their beliefs about mathematics instruction. The results indicate that participants' mathematical identities influence their preferred instructional strategies. Furthermore, survey results suggest that past experiences impact the development of an individual's mathematical identity and beliefs about math instruction. The absence of significant relationships between demographic factors and mathematical identities suggests the nuanced nature of identity development. This finding emphasizes the need to consider individual experiences and contexts to provide further explanation. The quantitative analysis, framed within Vygotsky’s sociocultural theory and Sfard and Prusak’s mathematical identity theory, provides valuable insights into the complex dynamics between personal experiences, beliefs, and instructional practices within the participants.
Discussion of Qualitative Findings

Bishop (2012) and Sfard and Prusak (2005) suggest that individual stories and narratives effectively reveal an individual’s mathematical identity. As a result, I conducted six semi-structured interviews. Two interview participants had low mathematical identity values, two had average identity values, and two teachers had high mathematical identity values. The interviews aimed to explain how personal experiences influence the formation of the teachers’ mathematical identities and describe how their identities influence their beliefs about effective math instruction. In this section, I discuss the results of the three qualitative research questions: How are teachers’ mathematical identities influenced by their experiences as math students and educators? How do teachers’ mathematical identities align with their preferences for instructional choices? and What beliefs do teachers report about the importance of learning math, and how does this relate to the teachers’ mathematical identities? For each question, I provide a brief overview of the findings and a discussion of the interpretation of the data in relation to the literature.

Discussion of Research Question 3: The Role of Past Experiences

The third research question explored how past experiences influenced educators' mathematical identities. This investigation uncovered complex connections between personal experiences and present beliefs. Research from Drake et al. (2001) and Drake and Sherin (2006) supports the connection between the dynamic nature of identity formation and the influence of lived experiences. Qualitative analysis of the interview data revealed two main themes that participants reported impacting their mathematical identities: experiences as students and experiences as adults/professionals.
The participants' reflections on their experiences as math students align with findings by Bray (2011) and Drake et al. (2001), who noted the profound impact of early educational encounters on developing mathematical identities. This study extends these findings by illustrating how specific positive or negative classroom experiences leave enduring impressions on educators, shaping their beliefs about teaching mathematics. The qualitative analysis found that positive recollections often centered on supportive teachers who fostered a sense of belonging and competence, while negative memories highlighted specific moments of struggle and anxiety. For example, Abigail shared, “I had an excellent third-grade math teacher. Everybody felt like they had a relationship with her.” This excerpt highlights the role of supportive educators in shaping positive mathematical identities. In contrast, Iris said, “I cheated in math... I remember having to go to the board to do races and the fear of having to perform in front of my peers. It is seared in my memory.” Iris’s narrative demonstrates the specific memories of struggle and anxiety that occurred during in-the-moment experiences in a math class.

Interestingly, research supports that constructing an individual’s math identity occurs over time through multiple lived experiences (Wood, 2013). However, the research does not suggest a difference between the impact of perceived positive versus negative experiences on the development of math identities. The results of this study indicate that individual negative experiences may have a more significant influence on the development of an individual’s math identity than individual positive memories. Furthermore, these findings suggest that individuals must have ongoing positive experiences with supportive teachers to help foster the development of a strong positive mathematical identity.
The research question also explored participants' experiences as adults and professionals. For different participants, these experiences either reaffirmed existing beliefs or prompted a shift in perspective. Evelyn credits experiences with her colleagues as fostering a shift in her thinking, saying, “I met some colleagues and became excited about planning for math. I never realized that you could be creative in math.” Conversely, Abigail's experiences in the classroom reaffirmed her focus on practical strategies for struggling learners, "I definitely know where my weaknesses are... So when I teach, I work hard to identify very specific strategies for my students so that they don’t fall into the same loopholes."

These examples bring to life the ongoing evolution of an individual’s mathematical identity. Furthermore, these results emphasize the complex nature of identity development and affirm that teachers’ mathematical identities can be changed over time. Research supports this finding, suggesting that adult and professional experiences can transform individuals’ mathematical identities (Sfard & Prusak, 2005; Wood, 2013). These findings contribute to understanding mathematical identity as a dynamic construct influenced by continuous reflection and new experiences. Additionally, the data suggests that teachers’ mathematical identities will continue to evolve as they encounter new experiences and engage in collaborative conversations about effective math instruction.

**Discussion of Research Question 4: Beliefs about Teaching Strategies**

This research question explored the link between educators' mathematical identities and their preferred pedagogical choices, focusing on their preferences for teaching strategies in mathematics education. Drawing on quantitative and qualitative data, this discussion delves into how participants’ mathematical identities shape their beliefs about instructional methods, aligning these findings with the current research.
Quantitative analysis revealed a strong preference among participants for collaborative problem-solving and discussion-based learning. This indicates a general preference for constructivist approaches that align with the mathematical reform movement (NCTM, 2018; Karatas et al., 2022). This finding suggests that, regardless of mathematical identity, teachers have begun to internalize the tenants associated with a more progressive math approach to teaching. Participants’ self-reported beliefs become clearer when analyzed through the context provided during the interviews. The qualitative data indicated that deep-rooted beliefs associated with participants’ math identities manifest when they describe their preferences for delivering math instruction. As a result, differences emerged between preferred teaching strategies and participants’ mathematical identities, and these differences were connected to the participants’ experiences with teaching strategies as students.

**Participants’ Experiences with Instructional Strategies as Students.** Research supports the importance of recollecting participants’ memories of traditional, procedure-focused instruction by acknowledging the impact of early educational experiences on later pedagogical choices (Bray, 2011; Drake et al., 2001). Participants’ narratives offer valuable context for understanding teachers’ current preferences and illustrate how past experiences serve as a backdrop against which individuals form new mathematical identities. The findings suggest that participants with a higher mathematical identity value are more likely to experience a transformation in which they value more progressive teaching strategies over traditional ones they experienced as students. In contrast, the findings show that educators with a lower math identity revert to more traditional strategies, especially when engaging struggling students. This finding agrees with the research that educators who see themselves as capable and confident in
mathematics are more likely to experiment with and value progressive student-centered teaching methods (Wood, 2013).

The transition in teaching strategy preferences among participants with higher mathematical identities suggests that professional development and collaboration can significantly evolve educators’ instructional approaches beyond their past experiences. This idea aligns with Boaler's (2015) argument for the transformative potential of problem-based collaborative instruction for students and teachers. Furthermore, there was no association between age or years of teaching experience and the paradigm shift to a more progressive approach. The lack of association indicates that educators can continue to shape and transform their mathematical identities and beliefs regardless of age. Maria put it best when she said, “I guess you can teach an old dog new tricks.”

**Self-Reported Preference for Instructional Strategies.** Participants with higher mathematical identities strongly preferred problem-based and discussion-oriented strategies when describing their preferred teaching practices. These participants’ preference for more progressive teaching strategies echoes the findings of Boaler (2015) and Boaler and Staples (2008), who highlighted the value of these methods in fostering deep mathematical understanding and positive student identities. For example, when I asked Evelyn to describe the teaching strategies she believed were the most effective in the math classroom today, she replied, “Communication is most important. I like to have students think-pair-share or do student talk with partner work with myself modeling last.” Evelyn and Iris, who had high math identity values, repeatedly commented on their preference for class discourse and rich discussions about problem-solving among students.
However, the variance in responses related to the importance of quick problem-solving and adherence to traditional teaching strategies suggests a nuanced relationship between mathematical identity and instructional preferences. Participants with lower math identity scores preferred more traditional teaching strategies, especially when working with struggling students. These participants placed a greater emphasis on quick problem-solving and the use of traditional strategies that they experienced as students. This finding mirrors the literature's discussions on the tension between traditional and reform-based instructional practices (Stipek et al., 2001).

It is clear that, although participants with lower math identities reported that they prefer problem-based learning and discussions, they often revert to traditional techniques when faced with challenges and struggling students. Abigail’s statement, “Even though it’s not in the manual, I taught the standard algorithm because I feel like you’re not going to be getting your base ten blocks and your hundreds chart out at the supermarket when you need to do these types of things” is a perfect example of the ingrained nature of traditional beliefs that form the foundation of her math identity. Abigail's excerpt reflects educators’ potential internal struggle to fully embrace reform-based strategies by highlighting the enduring influence of their educational experiences and identity on their teaching philosophy and beliefs.

**The Relationship Between Math Identity and Preferred Instructional Strategies.** The findings reveal distinct patterns for preferences in instructional strategies across the three mathematical identity groups. Group A participants, representing those with the lowest mathematical identity values, preferred more traditional, teacher-centered instructional approaches. Erin and Abigail relied on methods such as teaching algorithms, focusing on math facts, and prioritizing procedural fluency over conceptual understanding. Despite some efforts to incorporate open problem-solving approaches, they expressed reservations about their
effectiveness, reflecting a struggle between their experiences and pushing for more flexible problem-solving in the math classroom.

In contrast, Group C participants, with the highest mathematical identity values, preferred student-centered, discourse-rich instructional strategies. Iris and Evelyn emphasized fostering dialogue, promoting flexible thinking, and providing constructive feedback to support conceptual understanding. Their instructional approaches align closely with reform-oriented practices advocated by organizations like the National Council of Teachers of Mathematics (NCTM, 2018), reflecting a commitment to cultivating mathematical thinking and agency among students.

Group B participants, with average mathematical identity values, exhibited a mix of traditional and progressive instructional beliefs. Ann leaned towards traditional methods while incorporating strategies to alleviate test anxiety, whereas Maria favored student-centered approaches emphasizing conceptual understanding and student autonomy. These findings suggest a nuanced relationship between participants’ mathematical identities and their preferred teaching strategies, highlighting the influence of personal beliefs and experiences on instructional practice in the elementary math classroom.

Exploring the relationship between mathematical identity and teaching strategy preferences sheds light on the profoundly personal nature of teaching mathematics. The findings emphasize the importance of acknowledging and addressing the historical, emotional, and intellectual influences on educators' mathematical identities to foster instructional practices that support positive student outcomes in mathematics.

**Discussion of Research Question 5: Beliefs about the Importance of Learning Math**

The analysis of participants' beliefs about the importance of learning mathematics provided valuable insights into the manifestation of their mathematical identities. The emphasis
on traditional measures of success by participants with lower mathematical identity scores, such as Erin and Abigail from Group A, aligns with research findings. Stipek et al. (2001) highlighted that educators with a more traditional orientation toward mathematics instruction prioritize procedural knowledge and solutions. This finding suggests that teachers with a lower math identity will place a greater value on correctly applying mathematical strategies. This outcome-oriented approach aligns with the focus on applying procedural knowledge to achieve correct answers. Bishop (2012) identified this procedural focus as a concern, suggesting that traditional teaching beliefs often have a narrow conception of mathematical competence.

Conversely, the approach taken by participants with higher mathematical identity scores, like Iris and Evelyn in Group C, supports constructivist ideology emphasizing flexible thinking and discourse as prioritized instructional goals. Research findings back this belief by emphasizing the importance of fostering flexible thinking, collaboration, and perseverance, prioritizing understanding and problem-solving over rote memorization (Boaler & Greeno, 2000). Boaler and Selling’s (2017) longitudinal study further supports this finding by observing that students who engaged in collaborative problem-solving activities established positive mathematical identities and viewed mistakes as learning opportunities.

The manifestation of these opposing perspectives was evident in this study. Erin and Abigail both believed that procedural knowledge and the successful application of strategies are important. Erin’s response, “You teach a strategy, and then you teach another strategy, and then another strategy, and for these lower-level kids, that can be challenging, it’s too much,” demonstrates a focus on the mastery of each strategy individually. In contrast, Iris, who has a high mathematical identity score, shared, “Giving everyone an entry into every problem, giving everyone an entry into all the strategies and then giving them a choice. They’ve [students] got
tools in their toolbox; they can use a shoe to hammer in a nail.” These two perspectives demonstrate how individual mathematical identities manifest differently even when faced with the same task of teaching students problem-solving strategies. In Erin’s case, she perceived the strategies as skills that must be mastered, unlike Iris, who believes that strategies are tools for students to engage in productive problem-solving.

**The Importance of Establishing a Growth Mindset.** The study also revealed a shared belief among participants in the significance of fostering a growth mindset. The participants’ beliefs about the importance of fostering a growth mindset in their students align with Dweck’s (2016) research on the impact of growth mindsets on student achievement. Maria, Ann, Iris, and Evelyn’s commitment to promoting resilience reflects a paradigm shift that values the process of learning highlighted in the mathematical reform movement (NCTM, 2018). Furthermore, research suggests that classroom environments that support inquiry and the dynamic nature of learning will promote the development of a positive mathematical identity in students (Wood, 2013).

The teachers’ commitment to building mathematical classroom communities that foster a growth mindset that values the learning process and the outcome suggests a paradigm shift in current math instruction. Regardless of their mathematical identities, the participants recognized their responsibility to foster positive beliefs about their mathematical abilities in their students. Through the context of the qualitative data, it becomes evident that teachers who have experienced a transformation in their thinking value providing space for students to develop their mathematical perceptions. Both Iris and Evelyn describe the importance of providing space and time for students to explore their mathematical curiosities.
Connecting the Qualitative Discussion to the Theoretical Framework

The qualitative exploration of elementary math teachers' experiences and beliefs, situated within the theoretical framework of Vygotsky’s sociocultural theory and Sfard and Prusak’s mathematical identity theory, sheds light on the intricate relationship between mathematical identity and preferred instructional practices. By analyzing the qualitative results through these theoretical lenses, I present a deeper understanding of how social interactions and personal narratives influence teachers' perceptions of teaching mathematics.

Vygotsky’s Sociocultural Theory of Learning

Vygotsky’s sociocultural theory emphasizes the role of social interaction and cultural tools in developing cognitive functions (John-Steiner & Mahn, 1996). This theory is pivotal in understanding the qualitative findings of this study, particularly in relation to the teachers' reflections on their past experiences and current beliefs about effective instructional practices. The narratives of the interviewed teachers reveal how their social interactions, both as students and as professionals, have significantly shaped their beliefs and approaches to teaching mathematics.

For instance, teachers recounting positive experiences with former educators highlight the transformative power of supportive social interactions in fostering a confident and engaged approach to teaching mathematics. This finding aligns with Vygotsky's beliefs that learning occurs within a social context and that our cognitive development is deeply rooted in our interactions with others (John-Steiner & Mahn, 1996). The participants' accounts of preferring collaborative, dialogic instructional strategies further exemplify the high-value beliefs they place on sociocultural interactions, which informs their current pedagogical choices.
Sfard & Prusak’s Mathematical Identity Theory

Sfard and Prusak’s mathematical identity theory offers a framework for understanding how teachers perceive themselves and their relationship with mathematics. The qualitative results from this study illuminate the dynamic nature of mathematical identity among elementary math teachers. Teachers articulated their evolving mathematical identities through their stories, reflecting a continuous negotiation of self-perception as mathematicians and educators.

Teachers with strong mathematical identities often describe adopting instructional strategies that foster exploration, inquiry, and a growth mindset among students (Boaler & Greeno, 2000; Wood, 2013). This finding indicates how positive mathematical identities foster preferences for teaching strategies and beliefs that value mathematical thinking and understanding over procedural fluency. Conversely, teachers with less positive mathematical identities tend to lean towards traditional, algorithm-focused instructional strategies, suggesting that their experiences and self-perceptions significantly influence their teaching practices.

The interplay between teachers’ mathematical identities and their preference for certain instructional choices highlights the significance of narratives and lived experiences in shaping educational practices. This result aligns with Sfard and Prusak’s theory and highlights the role of personal and social narratives in constructing mathematical identities, which, by extension, inform preferences for teaching methodologies.

Analysis within the Theoretical Framework

By examining the qualitative data through the combined lenses of Vygotsky’s sociocultural theory and Sfard and Prusak’s mathematical identity theory, this research identifies how social interactions, cultural contexts, and personal experiences contribute to constructing mathematical identity and influence instructional preferences. The qualitative analysis recognizes
the complexity of teaching and learning mathematics and highlights the importance of acknowledging and addressing math education's sociocultural and identity-related aspects.

**Discussion of the Overarching Research Question**

This study investigated the manifestation of elementary teachers' mathematical identities through their self-reported beliefs. The overarching research question was: *How does an elementary teacher’s mathematical identity affect their self-reported beliefs about effective math instruction?* Throughout this chapter, I have presented the findings of this study within the context of the specific quantitative and qualitative research questions. My analysis and discussions bring to light the complexity of understanding the formation and manifestation of an individual’s mathematical identity. Research acknowledges this complexity and further identifies the tensions associated with identity studies. Bishop (2012) and Sfard and Prusak (2005) present the challenges of defining and framing mathematical identity studies, while Wood (2013) recognizes the difficulty in pinpointing the dynamic nature of identity development. Darragh's (2016) and Radovic et al.’s (2018) literature reviews acknowledge the importance of understanding mathematical identities while illuminating the multiple lenses through which research has been conducted.

In this section, I address the complex nature of studying mathematical identities by integrating the findings from each research question within a broader understanding. This section draws specific connections between the participants’ mathematical identities and overall beliefs about effective math instruction. I present this discussion through three themes: the impact of positive versus negative experiences, the perception versus reality of preferred teaching strategies, and the overarching beliefs about effective math instruction.
The Impact of Positive vs Negative Experiences

The results of this study recognize the significant influence that past experiences have on the formation of teachers’ mathematical identities. Of particular note was the difference in how participants recounted their positive versus negative experiences as students. Participants’ positive experiences often involved memories of personal relationships with teachers who demonstrated compassion and support. Participants described their feelings about teachers who made them believe in themselves or feel safe. Both Maria and Ann expressed this in their interviews, with Maria saying, “I was very blessed. I went to an extremely great elementary school, and those teachers are the ones who made me want to become a teacher.” Ann said, “I feel like I had really great teachers.” Evelyn shared, “When I went to college, I felt like the teacher wasn’t judging me. It helped me gain more confidence, and then I understood the importance of thinking flexibly with numbers.” In each example, the positive influence of teachers is ongoing, memorable, and formative.

These examples suggest that teachers cultivate a positive environment and community that shapes their students’ math identities. Research further highlights this finding by suggesting that the environment teachers cultivate and how they interact with their students can promote or hinder the development of positive math identities (Harper, 2019; Turner et al., 2013). Furthermore, the findings from this study suggest that our teachers understand and value cultivating a positive learning environment in their classrooms. This belief is evident in the near-unanimous agreement from the survey about teachers having a responsibility to foster a positive mindset in their students and in the interviews in which teachers acknowledged the importance of establishing a growth mindset in their classroom.
However, the clarity and detail by which participants recounted their negative experiences suggest these memories also have a lasting and meaningful impact on the development of an individual’s mathematical identity. Participants shared their stories of negative memories during the interviews. Abigail remembered hiding under a table in first grade and sobbing during a math class. Abigail said, “That is a very big motivating factor for me now as a teacher. I don’t want my students to feel the way I did then.” Bishop’s (2012) study also found that in-the-moment classroom experiences can have impressionable and lasting effects on students and their self-development.

Interestingly, these findings uncover a difference between the memories of specific negative experiences and the general positive environments and character traits reported by the participants. This suggests that significant negative experiences form lasting impressions that affect people well into adulthood. At the same time, positive memories become a construction of a supportive and nurturing time and place. This finding is important because elementary teachers often share how upset they get when students struggle in their math classes. Teachers empathize with their students and remember the negative experiences that shaped their identities.

This phenomenon becomes even more complicated when considering the value teachers place on establishing a growth mindset and positive nurturing environment in their classrooms. As a result, when students struggle, teachers may connect with their own negative experiences and internalize the belief that they are failing to support the establishment of a growth mindset with their students. The findings of this study suggest that teachers manifest student struggle as teacher failure and, therefore, are diligent and passionate about providing students with opportunities for success and a positive learning experience.
The Perception vs Reality of Preferred Teaching Strategies

This research sheds light on the intricate relationship between educators' mathematical identities and their pedagogical beliefs. The difference in emphasis between outcome-oriented instruction and a process-focused, growth-oriented approach suggests that mathematical identity influences teachers’ preferred instructional practices. As Sfard and Prusak (2005) suggest, the narratives educators tell about their mathematical journeys play a critical role in their teaching development and ultimately affect how they perceive and support their students' mathematical growth.

The findings of this study reveal the deep-rooted impact of mathematical identity on educational practices. Teachers with a more positive mathematical identity tend to favor progressive, constructivist teaching strategies that promote understanding problem-solving, and view mistakes as learning opportunities. Iris and Evelyn expressed these beliefs when I asked what teaching strategies they thought were most effective. Iris said, “Building a culture in the classroom where kids can make mistakes.” Evelyn shared, “I think providing students space to think and communicate is most important.” Their beliefs align with the mathematical reform movement’s ideologies. Boaler and Greeno’s (2000) study emphasizes that mathematical learning is most effective when it is interactive and collaborative and fosters a deeper conceptual understanding of procedural skill acquisition.

However, teachers with lower mathematical identity scores tend to adopt traditional, procedural, and outcome-oriented instructional strategies. Stipek et al. (2001) describe the struggle between traditional and progressive instructional practices, suggesting that traditional practices emphasize speed, accuracy, and procedural knowledge over conceptual understanding.
Erin and Abigail illuded to their preference toward traditional practices during their interviews. Erin expressed her belief that it is important to teach the standard algorithm and shared that she sees little value in manipulatives because students will only have access to them in the classroom. Abigail describes the tricks she teaches her students to “flip” numbers when working with subtraction or division. In both examples, Erin and Abigail rely on procedural knowledge and value the correct answer over conceptual understanding. Teachers’ mathematical experiences deeply influence their instructional preferences. Wood (2013) suggests that traditional experiences in mathematics can lead to a reliance on traditional methods. These teachers perceive these strategies as safer or more effective for ensuring student success.

**Synthesizing These Findings.** Although the data for this study was self-reported, these findings suggest that teachers’ mathematical identities not only shape their perceptions of effective math instruction but also influence the reality of their classroom practices. The participants in this study recognized the value and expressed a preference for progressive teaching strategies. However, during the interviews, participants with a lower math identity described the use and preference for more traditional strategies. This discrepancy between perception and preferred practice is further complicated by the challenges of aligning self-reported beliefs with known teaching strategies, especially when faced with the needs of struggling students.

Furthermore, participants' commitment to fostering a growth mindset signifies a common understanding of the importance of resilience, flexibility, and the belief in students’ potential to grow mathematically. However, these beliefs must match preferences for instructional strategies that support students' growth mindset development. Research suggests that the role of the teacher goes beyond beliefs and includes the effective execution of strategies that support the
development of positive identities in students (Harper, 2019; Turner et al., 2013). It is clear from the findings that teachers’ mathematical identities play a pivotal role in shaping their instructional choices. The results suggest that there may be a gap between teachers’ philosophy of effective math instruction and their preferred teaching strategies to support math instruction.

**Overarching Beliefs about Effective Math Instruction**

The study’s exploration of elementary teachers’ mathematical identities and their beliefs about teaching math culminates in a complex understanding of the overarching beliefs about effective math instruction. Through quantitative and qualitative analyses, a pattern emerges that shows a collective agreement among educators about the importance of fostering environments where mathematical learning is not just about acquiring procedural knowledge but also about nurturing the development of students’ confidence as capable mathematicians. However, I observed a tension between participants’ philosophical beliefs and their beliefs about the importance of learning mathematics.

**A Paradigm Shift Toward Progressive Math Ideology.** The participants’ alignment with progressive educational ideologies suggested a shared recognition of the importance of mathematical learning that goes beyond the confines of traditional practices. The move to embrace the mathematical reform movement’s beliefs represents a paradigm shift in math education. Research suggests this pedagogical shift is essential and will help to maximize student growth and achievement (Boaler & Greeno, 2000; Harper, 2019). Boaler and Greeno (2000) and Harper (2019) acknowledge the importance of conceptual understanding, problem-solving, and developing a growth mindset within math education. This study’s findings indicate a consensus among participants’ beliefs about the critical role of math in shaping cognitive development and preparing students for success in life. These beliefs align with Bishop (2012) and Sfard and
Prusak (2005), who highlighted the significant impact of mathematical learning on individuals' cognitive and personal growth.

The unanimous agreement among participants that fostering students' belief in their mathematical capabilities is a teacher's responsibility underscores an intrinsic commitment to cultivating positive mathematical identities. Evelyn shared this belief in her preference for being a student in today's math class. Evelyn believes "the confidence and time to communicate with my peers around math" would have positively influenced her math identity. Evelyn's statement echoes the progressive belief that contemporary instructional practices, characterized by discourse and collaboration, are essential for fostering positive mathematical identities and a deeper understanding of mathematical concepts (Boaler, 2013; Boaler & Selling, 2017).

The Tension between Philosophy and Beliefs about Instructional Practice. At the same time, the varying preferences among participants reveal diverse beliefs regarding the effectiveness of traditional versus modern math instructional strategies. For example, Erin shared, “I think that it would be okay to have a little of the old and a little of the new. The ultimate goal is, can you solve the problem?” Her appreciation for a blend of old and new teaching strategies and her focus on solving problems suggest a tension between integrating her beliefs that align with the reform movement and her preferences for traditional instructional techniques.

This tension was more evident in teachers with lower or average mathematical identities than in teachers with higher math identity values. Abigail shared her feelings, saying, “I know myself, so would the multiple strategies be overwhelming to me, or was it better that I was only taught one way?” Abigail’s statement suggests she values a more procedural approach to learning math and views success as being able to apply specific strategies successfully. In
contrast, Iris strongly preferred educational practices that support discourse, collaboration, and open problem solving. She highlighted the advantages of a more comprehensive and deeper understanding of mathematical concepts fostered by modern pedagogical methods. Iris's statement, “What my students are learning now is heads and shoulders above what they were learning just ten years ago,” demonstrates the belief in the evolution of math instruction towards more effective and inclusive strategies. This example suggests that teachers’ development of a positive mathematical identity may help bridge the gap between their philosophical support for the mathematical reform movement’s ideology and their preferences for specific teaching strategies to support this ideology in practice.

In synthesizing these findings, it becomes evident that elementary teachers' mathematical identities significantly influence their overarching beliefs about effective math instruction. While there is an inclination towards progressive, constructivist methodologies, the diversity in participants' experiences and preferences highlights the complexity and dynamic nature of teaching math. As educators navigate their mathematical journeys, their instructional choices are deeply intertwined with their personal beliefs, experiences, and identities.

Limitations

While conducting this study, I identified several limitations that require further discussion, including the sample's accurate population representation, the reliance on a limited number of participants from each recognized mathematical identity group, and the challenges associated with using self-reported data. I also discuss the limitations of conducting a mixed-methods study as they relate to my experience with academic research. In this section, I discuss each limitation and its impact on the generalizability and findings of the study.
**Representation of the Population**

A principal limitation of this study is the representation of the participant sample compared to the broader population of elementary teachers. Despite efforts to reach out to teachers across eight districts in southeastern Pennsylvania, the achieved sample size may only partially capture the diversity within the larger population of elementary math teachers. The eight districts that participated in the study have various demographics and student needs. With an estimated population of 550 teachers, my sample represents 9% of the total population. Therefore, whether the initial survey's sample size adequately represented each district’s unique population is unknown.

Furthermore, although I made a conscious effort to maximize the representation of a diverse range of mathematical identities for the qualitative interviews, the extent to which these participants represent the spectrum of identities among elementary math teachers remains a limitation. I was limited to participants willing to participate in the follow-up interviews. Only four teachers with a low mathematical identity and six with a high mathematical identity volunteered to participate in interviews. As a result, it is difficult to generalize the findings from the interviews to the larger population without first considering the related quantitative data. In response, I made every effort to present the qualitative findings in concert with the quantitative results to strengthen the generalizability of the findings.

Furthermore, the reliance on a limited number of representative participants for each mathematical identity profile created challenges in understanding each identity profile comprehensively. While coding and comparing data from two samples representing the same profile group helped identify common themes (Saldaña, 2015), this approach may not fully encompass the depth and breadth of experiences and beliefs held by all teachers within each
profile group. Creswell and Guetterman (2019) highlight the importance of accurate participant representation for generalizing findings. The dynamic and complex nature of mathematical identity research exasperates this limitation.

**Reliability and Validity of Self-reported Data**

Another significant limitation arose from the study's dependence on self-reported data. The accuracy and reliability of such data are inherently subject to the participants' interpretations of the survey questions and their willingness to respond candidly. Drawing from previously vetted questionnaires aimed to enhance the survey's reliability, yet the absence of previously established reliability statistics for the questionnaire used presents a challenge in confirming the findings' reliability. This limitation echoes concerns raised in the literature review regarding the complexity of studying mathematical identities, where the subjective nature of identity construction and the influence of social and cultural contexts (Boaler & Greeno, 2000; Sfard & Prusak, 2005) complicate the collection of objective and reliable data.

**Researcher Competence in Mixed Methods**

The competence required to conduct mixed-methods research effectively also represented a limitation. I designed this study with straightforward quantitative and qualitative research questions, and I tried to ensure the validity of the qualitative phase through multiple rounds of coding (Saldaña, 2015). However, the integration of quantitative and qualitative methods creates challenges. Creswell and Guetterman (2019) suggest that competence in navigating both quantitative and qualitative landscapes is crucial for a mixed-methods approach, and any limitations in this area may affect the study's overall robustness. This methodology introduces unique challenges, especially as a doctoral student embarking on my first research project.
Moreover, Creswell and Guetterman (2019) acknowledge the time-intensive nature of mixed-methods studies. Throughout this process, I had to achieve specific deadlines that caused me to reflect on my ability to conduct an accurate and meaningful analysis of the data sources. Conducting such comprehensive research within a constrained timeframe may limit the depth of engagement with the data and the thoroughness of the analysis, potentially impacting the richness and reliability of the findings.

**Limitations Associated with the Researcher’s Positionality**

One notable limitation stemming from my connection to the research is the potential influence of my biases and preconceived notions about mathematics education on the study. As someone deeply invested in the transformation of mathematics teaching practices to embrace problem-solving, collaboration, and responsive teaching, there is a risk that my enthusiasm for these approaches may inadvertently shape the framing of the research questions, the interpretation of the data, or the interactions with participants. Creswell and Guetterman (2019) suggest that researchers should critically examine their role, potential biases, and how these factors may affect the research process and outcomes.

My position as a male administrator in a field predominantly occupied by female teachers adds another layer of complexity, introducing power dynamics that could impact how participants respond to the research, potentially influencing their openness in sharing experiences and beliefs about math instruction. This dynamic requires careful navigation to minimize the influence of my position of authority on the research findings and ensure that the study reflects the authentic voices and experiences of the participants. To address this limitation, I used transparent communication about the study’s goals and maintained a stance of curiosity rather
than judgment to capture a genuine and diverse representation of teachers' mathematical identities and instructional beliefs.

**Overview of the Limitations**

These limitations underscore the need for further research to address the gaps identified in this study. Future studies could benefit from larger and more diverse samples to enhance the generalizability of findings. Additionally, developing and validating survey instruments tailored explicitly to exploring the connection between mathematical identity and instructional strategies in math education could strengthen the reliability of self-reported data.

**Implications for Practice**

After exploring the manifestation of beliefs about effective math instruction through the lens of elementary teachers’ mathematical identities, possible implications for practice emerged from the findings. In this section, I present possible applications of this research at the local, state, and national levels. At each level, I share common themes, including the importance of professional development, the acknowledgment of the role of the teacher in fostering positive student identities, and the commitment to promoting progressive mathematical teaching strategies.

This study illuminates the dynamic and complex manifestation of elementary teachers' mathematical identities. Through personal accounts of the positive and negative experiences that shaped participants' beliefs, it becomes clear that educators play a vital role in developing their students' mathematical sense of self. The study’s findings also indicate that elementary teachers often experience a gap between their support for the ideology of the math reform movement and the traditional teaching strategies they prefer to use in the classroom. Both findings suggest a strong need for professional development that transcends traditional pedagogical skill
enhancement and engages teachers in recognizing how their mathematical beliefs manifest in practice and affect students.

**Local Implications**

At the local level, schools could provide professional development opportunities that allow teachers the time to identify and reflect on their own mathematical identities. By giving teachers opportunities to bring into focus their beliefs, teachers can critically reflect on how their beliefs are manifesting in the classroom. This practice aligns with Boaler and Selling (2017) and Wood (2013), who suggest that engaging teachers in reflective practices that allow for the examination and development of their mathematical selves can foster a deeper, more meaningful engagement with mathematics instruction. To accomplish this, schools should provide professional development settings that mirror classroom experiences and promote positive identity development (Wood, 2013).

Furthermore, the participants' collective acknowledgment of teachers’ pivotal role in fostering students’ confidence in mathematics resonates with the mathematical reform movement and the tenets of a growth mindset (Dweck, 2016; NCTM, 2018). Local educational agencies could provide professional development on implementing classroom norms and practices that champion learning processes that support math reform ideology and encourage students to view challenges not as insurmountable obstacles but as opportunities for growth and learning. Such an approach aligns with the mathematical reform movement's advocacy for engaging teachers and students in problem-solving, conceptual understanding, and discourse (NCTM, 2018).

Finally, districts could evaluate their curriculum and resources to assess their alignment with progressive teaching practices. Schools must provide and support progressive instructional strategies to encourage the practical shift toward collaborative problem-based math instruction.
Schools should engage teachers in experiences demonstrating the effectiveness of discourse-based math instruction while simultaneously identifying the potential challenges of implementing traditional teaching strategies.

Educators and administrators should embrace instructional methodologies prioritizing conceptual understanding, collaborative problem-solving, and meaningful discourse. Embracing these methodologies aligns with the philosophical underpinnings of the mathematical reform movement. It underscores the necessity of equipping teachers with the resources and support to implement these strategies effectively (NCTM, 2018). As a result, administrators could set school-wide goals focusing on implementing instructional strategies that foster collaboration and growth mindsets in elementary math classrooms.

**State-Level Implications**

The state-level implications of this study call for a broader systemic approach to fostering equitable and effective mathematics education. State boards of education could advocate for policies that mandate ongoing professional development opportunities for teachers and provide state-level resources to support districts’ delivery of effective professional development related to the manifestation of teachers’ mathematical identities in the classroom. State educational policies should highlight the significance of the pedagogical shift in math instruction and emphasize the critical role of positive mathematical identities in enhancing instructional effectiveness.

It is also important for state-level educational agencies to evaluate and update standards, resources, and assessments to accurately reflect and prioritize the goals of problem-solving and flexible thinking with numbers. The mathematical common core standards include mathematical practices and emphasize problem-solving and explanation. However, state tests often focus on
computational skills related to specific eligible content (PA Department of Education, 2022). States should curate a bank of resources and training materials that support districts in shifting instructional practices to better align with the mathematical reform movement.

**National Implications**

At the national level, the implications of this research suggest that teacher preparation programs should be updated to engage future educators in mathematical identity concepts. A critical step would be for higher education institutions to integrate the concepts that support positive mathematical identity development within the standards of their teacher education programs. This recommendation is rooted in recognizing educators' mathematical identities' profound impact on their pedagogical choices and, consequently, on students' mathematical learning experiences. By embedding content on mathematical identity, growth mindset, and culturally responsive teaching practices into teacher preparation programs, we set the stage for a future where educators are proficient in pedagogical skills and champions of positive identity formation in mathematics.

The findings of this study identify the profound connection between teachers' mathematical identities and their pedagogical choices, shedding light on the transformative potential of professional development tailored to explore educators’ mathematical identities. Prioritizing professional development opportunities that mirror the desired classroom dynamics and promote the development of positive mathematical identities, local, state, and national educational agencies can support the shift towards more collaborative, problem-solving-based instruction. Providing mathematical identity professional development for educators will help realize the mathematical reform movement's advocacy for educational practices that champion conceptual understanding, collaborative problem-solving, and meaningful discourse.
Recommendations for Future Research

Sfard and Prusak (2005) recognize the intricate relationship between teachers' early mathematical experiences and professional identities. Furthermore, studying mathematical identities is complex and dynamic (Darragh, 2016). As a result, there is a need for further investigation into how teachers’ personal experiences influence the development of their mathematical identities and manifest in instructional practice. This section explores possible areas of future research related to the findings from this study.

Exploring Teachers’ Positive and Negative Experiences

Wood (2013) recognizes that teachers' memories of their mathematical experiences, both positive and negative, shape their identities and preferred instructional approaches. This study found that teachers process their negative versus positive experiences differently in relation to the development of their mathematical identities. Future research could explore the extent to which specific negative experiences versus ongoing positive environments shape and influence teachers' mathematical identity development. This research would provide additional knowledge on the most effective ways to foster the development of students’ positive math identities. These studies could employ narrative inquiry to uncover the depth of influences and provide greater context for how individuals reify their mathematical identities through experiences.

Effective Professional Development

Boaler and Selling (2017) found that effective professional development for teachers includes experiences with problem-based collaborative learning strategies. Furthermore, this study suggests that shared professional experiences can help teachers adopt new instructional strategies. However, it is unclear what the most effective ways are to engage teachers in this type of professional learning. Further research into effective professional development could yield
important insights into how teachers' mathematical identities evolve in response to professional interactions and how they manifest in instructional practice. For example, this study noted the discrepancy between teachers' support for the math reform movement and their preference for traditional teaching methods. Future research could investigate the specific types of professional development that help teachers bridge the gap between their mathematical identities and the pedagogical practices endorsed by the mathematical reform movement.

Research by Boaler (2013) and Wood (2013) on the formation of mathematical identities within the context of teacher education programs indicates that further investigation into these programs is needed. Future studies could provide insights into how future educators develop their mathematical identities through their collegiate experiences. Case studies of specific teacher preparation programs may provide additional knowledge about the coursework and resources that most effectively promote positive math identities in the students. Furthermore, a study investigating the prevalence of mathematical identity content in university programs could provide needed information about how future educators may change the landscape of schools as they enter the workforce.

**Longitudinal Studies**

The mathematical reform movement is well established, and the findings of this study suggest that teachers have already begun to adopt the associated ideologies. However, tensions exist between constructivist and positivist ideologies surrounding effective math instruction (Steenbergen-hu et al., 2016). There is a lack of longitudinal data that connects students' experiences with traditional versus progressive math instructional strategies and their overall growth, achievement, and success in future math-related endeavors. As a result, additional
research is needed to determine the comprehensive effectiveness of teaching strategies aligned with the mathematical reform movement.

Boaler & Selling’s (2017) longitudinal study is one of the few that connects participants’ educational experiences with future career choices. However, the sample size was limited, so additional research is needed to explore this area of interest. In addition, longitudinal studies into the long-term evolution of individuals’ mathematical identities may provide a greater understanding of how people reify their identities over time. This information will help identify critical moments when people are most susceptible to changing their mathematical beliefs. A mixed-method design would support the necessary synthesis of large amounts of data associated with a longitudinal study of this type.

The study of mathematical identities and their influence on teaching practices highlights a critical area for future research. Future investigations should focus on understanding the specific impact of teachers' past experiences on their mathematical identities and how these, in turn, affect their instructional beliefs. Additionally, research into targeted professional development could provide strategies to align teachers' identities with reform-oriented teaching practices. Longitudinal studies are also essential to assess the long-term impact of mathematical identities on educational outcomes. By exploring these themes, future research can offer valuable contributions to mathematics education, supporting the development of positive mathematical identities for teachers and students.

Summary

This chapter discussed the findings of my explanatory sequential mixed-methods study investigating the intricate relationship between elementary teachers' mathematical identities and their self-reported beliefs about effective math instruction. This research aimed to illuminate how
the complex interplay of teachers' mathematical identities shapes their instructional beliefs and strategies, ultimately influencing student achievement in mathematics.

Through analysis of quantitative data gathered from elementary math teachers across eight districts in southeastern Pennsylvania, coupled with in-depth qualitative insights from semi-structured interviews, this study has contributed valuable findings to the field of mathematics education. The findings highlight teachers' mathematical identities' complex and dynamic nature and provide insight into how past experiences shape their beliefs about math instruction. The study discovered a shift in preference among teachers with more positive mathematical identities towards progressive, student-centered teaching strategies, suggesting that enhancing teachers' mathematical identities could bridge the gap between educational ideology and classroom practice.

Addressing the overarching research question, this study found that elementary teachers' mathematical identities profoundly affect their beliefs about and approaches to math instruction. Teachers with positive identities preferred constructivist methods that foster understanding and collaboration. In contrast, those with less positive identities shared that they reverted to traditional, procedural strategies, especially when teaching struggling students. In summary, the findings and discussions presented in this chapter contribute to a deeper understanding of the role of mathematical identities in shaping educational practices. They underscore the importance of fostering positive identities among teachers to promote progressive, effective math instruction that aligns with the goals of the mathematical reform movement.
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### Appendix A: Participants’ Demographics from Phase 1

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<td>3rd, 5th</td>
</tr>
<tr>
<td>Female</td>
<td>Master's Degree</td>
<td>51-55</td>
<td>26-30</td>
<td>2nd</td>
</tr>
<tr>
<td>Female</td>
<td>Master's Degree</td>
<td>51-55</td>
<td>1-5</td>
<td>3rd</td>
</tr>
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<td>Gender</td>
<td>Education Level</td>
<td>Age Range</td>
<td>Teaching Experience in Years</td>
<td>Grade Levels Taught</td>
</tr>
<tr>
<td>----------------</td>
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<tr>
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<td>Master's Degree</td>
<td>41-45</td>
<td>16-20</td>
<td>1st</td>
</tr>
<tr>
<td>Female</td>
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<td>41-45</td>
<td>16-20</td>
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</tr>
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<td>26-30</td>
<td>1-5</td>
<td>3rd</td>
</tr>
<tr>
<td>Female</td>
<td>Master's Degree</td>
<td>46-50</td>
<td>21-25</td>
<td>5th</td>
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<tr>
<td>Female</td>
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<td>51-55</td>
<td>26-30</td>
<td>2nd</td>
</tr>
<tr>
<td>Male</td>
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<td>26-30</td>
<td>1-5</td>
<td>2nd</td>
</tr>
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<td>Female</td>
<td>Master's Degree</td>
<td>26-30</td>
<td>1-5</td>
<td>3rd</td>
</tr>
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<td>Female</td>
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<td>36-40</td>
<td>11-15</td>
<td>4th</td>
</tr>
<tr>
<td>Female</td>
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<td>31-35</td>
<td>11-15</td>
<td>4th</td>
</tr>
<tr>
<td>Female</td>
<td>Master's Degree</td>
<td>51-55</td>
<td>26-30</td>
<td>4th</td>
</tr>
<tr>
<td>Female</td>
<td>Master's Degree</td>
<td>41-45</td>
<td>16-20</td>
<td>4th</td>
</tr>
<tr>
<td>Female</td>
<td>Undergraduate Degree</td>
<td>26-30</td>
<td>6-10</td>
<td>2nd</td>
</tr>
<tr>
<td>Female</td>
<td>Master's Degree</td>
<td>31-35</td>
<td>6-10</td>
<td>4th</td>
</tr>
<tr>
<td>Female</td>
<td>Master's Degree</td>
<td>26-30</td>
<td>1-5</td>
<td>3rd</td>
</tr>
<tr>
<td>Female</td>
<td>Master's Degree</td>
<td>26-30</td>
<td>6-10</td>
<td>3rd, 4th, 5th</td>
</tr>
<tr>
<td>Female</td>
<td>Master's Degree</td>
<td>51-55</td>
<td>21-25</td>
<td>3rd, 4th, 5th</td>
</tr>
<tr>
<td>Female</td>
<td>Master's Degree</td>
<td>56-60</td>
<td>26-30</td>
<td>2nd</td>
</tr>
<tr>
<td>Female</td>
<td>Master's Degree</td>
<td>31-35</td>
<td>6-10</td>
<td>1st</td>
</tr>
<tr>
<td>Prefer Not to Say</td>
<td>Master's Degree</td>
<td>56-60</td>
<td>21-25</td>
<td>1st</td>
</tr>
<tr>
<td>Female</td>
<td>Master's Degree</td>
<td>36-40</td>
<td>11-15</td>
<td>3rd</td>
</tr>
<tr>
<td>Female</td>
<td>Master's Degree</td>
<td>31-35</td>
<td>6-10</td>
<td>1st, 2nd, 3rd, 4th, 5th</td>
</tr>
<tr>
<td>Male</td>
<td>Master's Degree</td>
<td>46-50</td>
<td>21-25</td>
<td>5th</td>
</tr>
<tr>
<td>Female</td>
<td>Undergraduate Degree</td>
<td>20-25</td>
<td>1-5</td>
<td>2nd</td>
</tr>
<tr>
<td>Female</td>
<td>Master's Degree</td>
<td>41-45</td>
<td>11-15</td>
<td>1st</td>
</tr>
</tbody>
</table>

*Note.* All data shown was self-reported from the initial survey.
Appendix B: Phase 1 Quantitative Survey

Block 1: Consent

Informed Consent Notification

Project Title: The Manifestation of Elementary Teachers' Mathematical Identity; An Explanatory Mixed Methods Study
Investigator(s): Kyle Brun (Primary Investigator), Merry Stauls (WCU Faculty Advisor)

Project Overview: Participation in this research project is voluntary and is being done by Kyle Brun as part of their Doctoral Dissertation to: investigate the effects that teachers' self-reported mathematical identities have on their preferred mathematical instructional practices.

Your participation will take about 15 minutes to complete an initial questionnaire. Upon consent, follow-up interviews will take about 45 minutes and be conducted virtually through Zoom. To participate in the study you will be asked to: provide consent to take the initial questionnaire, take the questionnaire, provide consent to participate in a follow-up interview, if selected, participate in the follow-up interview, and then provide feedback on analysis and findings of your interview.

There is a minimal risk that participants may experience mild discomfort or anxiety when reflecting upon past mathematical experiences. If you experience discomfort, you have the right to withdraw at any time or choose to not answer a question. There are no incentives provided for participation.

This research will help school leaders and teachers recognize instructional strategies that may promote or prevent the development of positive mathematical identities in students. Furthermore, a deeper understanding of how teachers' mathematical identities influence their teaching practices may help districts develop and provide

https://wcap.ui.qualtrics.com/Q/EdSolutions/Blocks/ Ajax/GetSurveyPreview?ContextSurveyID=SY_5iGKk2hXtrn24jRYOA&ContextLibraryID=UR_5GkBd... 1/11
Interview participants are identified and scheduled. Following the transcription of the interviews, all identifiable data will be coded or destroyed. Video/audio recordings will be erased following transcription. Records will be destroyed Three Years After Study Completion.

7. Do I get paid to take part in this study?
No

8. Who do I contact in case of research-related injury or if I have questions about the study?
For any questions about this study, contact: Primary Investigator: Kyle Brun at 484-574-7208 or kb985201@wcupa.edu and/or Faculty Sponsor: Merry Staulters at 610-436-2398 or mstaulters@wcupa.edu

9. What will you do with my Identifiable Information?
Your information will not be used or distributed for future research studies.

For any questions about your rights in this research study, contact the ORSP at 610-436-3557.

If you agree to participate, you are agreeing to the following statement:

I have read this form and I understand the statements in this form. I know that if I am uncomfortable with this study, I can stop at any time. I know that it is not possible to know all possible risks in a study, and I think that reasonable safety measures have been taken to decrease any risk.

If you agree to participate, check, “YES, I agree to participate” and you will be directed to the survey. If you do not agree to participate, check, “NO, I do not agree to participate” and you will be directed to the end of the survey where you may exit.

This study has been approved by the West Chester University Institutional Review Board, IRB number: IRB-FY2023-360.

- Yes, I consent to participate
- No, I do NOT wish to participate
Block 2: Inclusion Criteria

Do you hold a valid PA Elementary Teaching Certification?
- Yes
- No

Do you currently teach math to students in first through fifth grade?
- Yes
- No

Do you have at least one full year of experience teaching elementary math?
- Yes
- No

Are you currently a full time, contracted teacher within a Pennsylvania school district?
- Yes
- No

Block 3: Demographics- Complete the following demographic questions

What is your gender identity?
- Male
- Female
- Non-binary / third gender
- Prefer not to say

What is the highest level of education that you have obtained?
O Undergraduate degree
O Master's Degree or Master's Equivalent
O Doctoral Degree
O other

What is your age?
O 20-25
O 25-30
O 31-35
O 36-40
O 41-45
O 46-50
O 51-55
O 56-60
O 61-65
O 66 and up

How many years of teaching experience do you have teaching 1st - 5th grade in a Pennsylvania public school?
O 1-5
O 6-10
O 11-15
O 16-20
O 21-25
O 26-30
O 30+  

What grade level(s) do you currently teach math? Select all that apply
☐ 1st Grade  
☐ 2nd Grade  
☐ 3rd Grade  
☐ 4th Grade  
☐ 5th Grade  
☐ Other (Please Specify)

Which Pennsylvania teaching certificate(s) do you hold (Select all that apply)?

☐ Early Childhood Education N-3 (discontinued 8/31/2013)  
☐ Elementary Education K-6 (discontinued 8/31/2013)  
☐ Grades 4-8 (List your concentrations ex. ELA, Math, Science, and/or Social Studies)

☐ Grades Pre-Kindergarten – 4  
☐ Special Education  
☐ Other (Please Specify)

Block 4: Questionnaire

The following are statements related to your personal math identity. Respond to each statement below using the provided scale. Choose the answer that BEST represents your beliefs about your own math ability and experiences.

<table>
<thead>
<tr>
<th></th>
<th>Strongly disagree</th>
<th>Somewhat disagree</th>
<th>Neither agree nor disagree</th>
<th>Somewhat agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I enjoyed math class when I was in school.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I believe that I am good at math.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I believe that math is</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

https://wezpa.co1.qualtrics.com/QR/Section/Blocks/Ajax/GetSurveyPrintPreview?ContextSurveyID=SV_SGGKROmuz24pKYOOkContextLibraryID=UR_eGSt... 7/11
<table>
<thead>
<tr>
<th>Question</th>
<th>Strongly disagree</th>
<th>Somewhat disagree</th>
<th>Neither agree nor disagree</th>
<th>Somewhat agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I believe that solving math problems quickly is important.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I believe that getting the right answer is the most important thing in math.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I believe that my math education was effective.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I enjoy teaching math.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I am confident in my mathematical abilities as an educator.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I was a good math student in school.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I can understand even the most difficult mathematical concepts.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I am interested in mathematics.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I like to learn new ways to solve math problems.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

The following statements are related to your beliefs about other’s math abilities. Respond to each statement below using the provided scale. Choose the answer that BEST represents your beliefs.
<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly disagree</th>
<th>Somewhat disagree</th>
<th>Neither agree nor disagree</th>
<th>Somewhat agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I believe that some people just don't get math.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I believe that some people are born with brains that work in ways that are just better for math and science.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I believe that it is important that people are able to explain their reasoning in math.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I believe that people see value in what they learn in math class.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I believe that the concepts people learn in math class are vital to their success in life.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

The following are statements related to your beliefs about teaching math. Respond to each statement below using the provided scale. Choose the answer that BEST represents your beliefs.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly disagree</th>
<th>Somewhat disagree</th>
<th>Neither agree nor disagree</th>
<th>Somewhat agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I believe that it is my responsibility to build my students' beliefs that they are good at math.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>I like to teach using the same strategies</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Strongly disagree</td>
<td>Somewhat disagree</td>
<td>Neither agree nor disagree</td>
<td>Somewhat agree</td>
<td>Strongly agree</td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>-------------------</td>
<td>---------------------------</td>
<td>----------------</td>
<td>----------------</td>
<td></td>
</tr>
<tr>
<td>that I was exposed to as a math student. I believe that expectations for math instruction have changed throughout my career. I prefer instructional strategies that maximize collaborative problem solving. I believe that students learn best when they engage in discussions about problem solving. I believe that feedback on how students engage with math problems that is not centered on the final answer is valuable.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Block 5: Solicitation for Participation in Follow Up Interview**

Would you be willing to participate in a follow up interview through Zoom?

- Yes
- No

**Block 6: Contact Information**

Thank you for your willingness to participate in a follow-up interview. If you are selected to participate, Kyle Brun will contact you via email when it is time to schedule your
Zoom interview.

What is your preferred email for contact?

You indicated that you would be willing to participate in a follow-up interview but did not provide a valid email address. If you have decided that you would not like to participate in a follow-up interview please leave this question blank.

What is your preferred email for contact?
Appendix C: Phase 2 Qualitative Interview Questions

Interview Protocol

Researcher: The purpose of this interview is to get a deeper understanding of how elementary math teachers develop their mathematical identity and how your mathematical identity may influence your beliefs about math instruction. Your mathematical identity is how you see yourself as a mathematician, or put another way, it is your beliefs about your own math abilities. At any time, you can not answer a question or ask for the interview to be over. To protect your confidentiality, I will change your name (or have participants change their name) on the Zoom screen to a pseudonym. During the interview, please do not share identifying information or use the names of specific students, teachers, or schools/districts. I will record the video and audio of this Zoom meeting and delete the recording once it has been transcribed and checked for accuracy. If you are uncomfortable with the video recording, you may turn off your camera anytime during the interview.

After transcribing and coding the interview, I will allow each participant to check my interpretations of what was communicated. I will send each participant an email with my findings. You can review my findings and provide clarifications or corrections to any misinterpreted information by the date indicated in the email. Do you have any questions about this process?

I am about to start the recording, and the first thing we will review is the consent to participate in this interview.

Start Zoom Recording
I have put a link to the consent form in the chat and will share my screen and review the consent form with you at this time. If you have any questions, please do not hesitate to ask. After reviewing the consent form, I will ask you for verbal consent to continue participating in the interview.

If you are ok with proceeding, can you please signify by verbally saying, “After reviewing the consent form, I am willing to participate in this interview and study.”

Wait for responses

Reminder: Please know that you do not have to answer any question you do not want to answer and you can stop the interview at any time.

Interview Questions:

1. Think back to when you were an elementary student in a math class, did you like learning math? Why or why not?

2. As a student, did you think you were good at math? How about now as a teacher?

3. Describe some teaching strategies you remember your elementary teachers using in math class. Did you think they were effective?

4. How did your experiences with math as a student compare to how you teach math as an educator?

5. How has your mathematical identity evolved over time? What were some key moments that shaped your identity?
6. How do you provide feedback to your students? How does this compare to how you received feedback as a student?

7. What teaching strategies do you believe are most effective in your classroom?

8. Would you prefer to be a student in today’s math class or repeat the experience you had as a student growing up? Why?
### Mixed Method Research Questions

*How does an elementary teacher’s mathematical identity affect their self-reported beliefs about effective math instruction?*

<table>
<thead>
<tr>
<th>Research Question (RQ)</th>
<th>Questionnaire Items</th>
<th>Interview Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>RQ1 (Quant): What percent of educators surveyed report developing a positive versus negative mathematical identity?</td>
<td>Questions 12.2, 12.3, 12.5*, 12.8, 12.10, 12.11, 12.12, 13.1*, 13.2*</td>
<td></td>
</tr>
<tr>
<td>RQ2 (Quant): Is there a relationship between the reported demographics of teachers and their self-identified mathematical identities?</td>
<td>Questions 6-11 (Demographics Block) Questions 12.2, 12.3, 12.5*, 12.8, 12.10, 12.11, 12.12, 13.1*, 13.2*</td>
<td></td>
</tr>
<tr>
<td>RQ3 (Qual): How are teachers’ mathematical identities influenced by their experiences as math students and educators?</td>
<td>Questions 12.1, 12.6, 12.9, 14.3</td>
<td>Questions 1, 2, 4, 5</td>
</tr>
<tr>
<td>RQ5 (Qual): What beliefs do teachers report about the importance of learning math, and how does this relate to the teachers’ mathematical identities?</td>
<td>Questions 13.3, 13.4, 13.5, 14.1</td>
<td>Question 4, 6, 8</td>
</tr>
</tbody>
</table>

*Indicates the scale was reversed during statistical analysis
Demographics Questions

Start of Block: Block 3: Demographics- Complete the following demographic questions

Q6. Gender What is your gender identity?
   o Male (1)
   o Female (2)
   o Non-binary / third gender (3)
   o Prefer not to say (4)

Q7. Education What is the highest level of education that you have obtained?
   o Undergraduate degree (4)
   o Masters Degree or Masters Equivalent (5)
   o Doctoral Degree (6)
   o I am unsure (7)

Q8. Age What is your age?
   o 20-25 (4)
   o 25-30 (5)
   o 31-35 (6)
   o 36-40 (7)
   o 41-45 (8)
   o 46-50 (9)
   o 51-55 (10)
   o 56-60 (11)
   o 61-65 (12)
   o 66 and up (13)
Q9. Teaching Exp How many years of teaching experience do you have teaching 1st - 5th grade in a Pennsylvania public school?
   o 1-5 (4)
   o 6-10 (5)
   o 11-15 (6)
   o 16-20 (7)
   o 21-25 (8)
   o 26-30 (9)
   o 30+ (10)

Q10. Grade Level In what grade level(s) do you currently teach math? Select all that apply
   □ 1st Grade (1)
   □ 2nd Grade (2)
   □ 3rd Grade (3)
   □ 4th Grade (4)
   □ 5th Grade (5)
   □ Other (6)

Q11. PA Cert Which Pennsylvania teaching certificate(s) do you hold (Select all that apply)?
   □ Early Childhood Education N-3 (discontinued 8/31/2013) (1)
   □ Elementary Education K-6 (discontinued 8/31/2013) (2)
   □ Grades 4-8 (ELA, Math, Science, or Social Studies) (3)
   □ Grades Pre-Kindergarten – 4 (4)
   □ Special Education (5)
   □ Other (6)

End of Block: Block 3: Demographics- Complete the following demographic questions
Q.12 The following are statements relate to your personal math identity. Respond to each statement below using the provided scale. Choose the answer that BEST represents your beliefs about your own math ability and experiences.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly disagree</th>
<th>Somewhat disagree</th>
<th>Neither agree nor disagree</th>
<th>Somewhat agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I enjoyed math class when I was in school.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>I believe that I am good at math.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>I believe that math is useful in my daily life.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>I believe that solving math problems quickly is important.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>I believe that getting the right answer is the most important thing in math.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>I believe that my elementary math education was effective.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Statement</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>--------------------------------------------------------------------------</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>I enjoy teaching math.</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>I am confident in my mathematical abilities as an educator.</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>I was a good math student in elementary school.</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>I can understand even the most difficult mathematical concepts.</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>I am interested in mathematics.</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
<tr>
<td>I like to learn new ways to solve math problems.</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
<td>o</td>
</tr>
</tbody>
</table>

Q.13 The following statements related to your beliefs about other's math abilities. Respond to each statement below using the provided scale. Choose the answer that BEST represents your beliefs.
<table>
<thead>
<tr>
<th>Strongly disagree (1)</th>
<th>Somewhat disagree (2)</th>
<th>Neither agree nor disagree (3)</th>
<th>Somewhat agree (4)</th>
<th>Strongly agree (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I believe that some people just don't get math. (1)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>I believe that some people are born with brains that work in ways that are just better for math and science. (2)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>I believe that it is important that people are able to explain their reasoning in math. (3)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>I believe that people see value in what they learn in math class. (4)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>I believe that the concepts people learn in math class are vital to their success in life. (5)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Q14 The following are statements relate to your beliefs about teaching math. Respond to each statement below using the provided scale. Choose the answer that BEST represents your beliefs.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly disagree (1)</th>
<th>Somewhat disagree (2)</th>
<th>Neither agree nor disagree (3)</th>
<th>Somewhat agree (4)</th>
<th>Strongly agree (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I believe that it is my responsibility to build my students' beliefs that they are good at math.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>I try to teach using the same strategies that I was exposed to as a math student.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>I believe that expectations for math instruction have changed throughout my career.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>I choose instructional strategies that maximize collaborative problem-solving.</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>I believe that students learn best when they engage in discussions about</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
I provide feedback on how students engage with math problems that are not centered on the final answer.

End of Block: Block 4: Questionnaire

Interview Questions:
1. Think back to when you were an elementary student in a math class, did you like learning math? Why or why not?
2. As a student, did you think you were good at math? How about now as a teacher?
3. Describe some teaching strategies you remember your elementary teachers using in math class. Did you think they were effective?
4. How did your experiences with math as a student compare to how you teach math as an educator?
5. How has your mathematical identity evolved over time? What were some key moments that shaped your identity?
6. How do you provide feedback to your students? How does this compare to how you received feedback as a student?
7. What teaching strategies do you believe are most effective in your classroom?
8. Would you prefer to be a student in today’s math class or repeat the experience you had as a student growing up? Why?
Appendix E: IRB Approval

Sep 28, 2023 8:29:04 AM EDT

To: Kyle Brun
Col of Education & Social Work, Ed Leadership & Higher Ed Adm

Re: Expedited Review - Initial - IRB-FY2023-360 The Manifestation of Elementary Teachers’ Mathematical Identity; An Explanatory Mixed Methods Study

Dear Kyle Brun:

Thank you for your submitted application to the West Chester University Institutional Review Board. Since it was deemed expedited, it was required that two reviewers evaluated the submission. We have had the opportunity to review your application and have rendered the decision below for The Manifestation of Elementary Teachers’ Mathematical Identity; An Explanatory Mixed Methods Study.

Decision: Approved

Selected Category: 6. Collection of data from voice, video, digital, or image recordings made for research purposes. 7. Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies. (NOTE: Some research in this category may be exempt from the HHS regulations for the protection of human subjects. 45 CFR 46.101(b)(2) and (b)(3). This listing refers only to research that is not exempt.)

Sincerely,
West Chester University Institutional Review Board

IORG#: IORG0004242
IRB#: IRB00005030
FWA#: FWA00014155
Appendix F: Consent Form

Block 1: Consent

Informed Consent Notification

Project Title: The Manifestation of Elementary Teachers’ Mathematical Identity; An Explanatory Mixed Methods Study
Investigator(s): Kyle Brun (Primary Investigator), Merry Staulders (WCU Faculty Advisor)

Project Overview: Participation in this research project is voluntary and is being done by Kyle Brun as part of their Doctoral Dissertation to: investigate the effects that teachers’ self-reported mathematical identities have on their preferred mathematical instructional practices.

Your participation will take about 15 minutes to complete an initial questionnaire. Upon consent, follow-up interviews will take about 45 minutes and be conducted virtually through Zoom. To participate in the study you will be asked to; provide consent to take the initial questionnaire, take the questionnaire, provide consent to participate in a follow-up interview, if selected, participate in the follow-up interview, and then provide feedback on analysis and findings of your interview.

There is a minimal risk that participants may experience mild discomfort or anxiety when reflecting upon past mathematical experiences. If you experience discomfort, you have the right to withdraw at any time or choose to not answer a question. There are no incentives provided for participation.

This research will help school leaders and teachers recognize instructional strategies that may promote or prevent the development of positive mathematical identities in students. Furthermore, a deeper understanding of how teachers’ mathematical identities influence their teaching practices may help districts develop and provide
targeted professional development to their staff.

The research project is being done by Kyle Brun as part of their Doctoral Dissertation. The purpose of this study is to investigate the effects that teachers’ self-reported mathematical identities have on their preferred mathematical instructional practices. In the most simplistic form, mathematical identities manifest in the statements, “I am good at math” or “I am not good at math”.

If you would like to take part, West Chester University requires that you agree and sign this consent form.

You may ask Kyle Brun any questions to help you understand this study. If you don’t want to be a part of this study, it won’t affect any services from West Chester University or have any repercussions from your district of employment. If you choose to be a part of this study, you have the right to change your mind and stop being a part of the study at any time.

1. What is the purpose of this study?
In the most simplistic form, mathematical identities manifest in the statements, “I am good at math” or “I am not good at math”. The purpose of this study is to investigate the effects that teachers’ self-reported mathematical identities have on their preferred mathematical instructional practices.

2. If you decide to be a part of this study, you will be asked to do the following:
   - provide consent to participate in the study Complete a questionnaire (estimated 15 minutes)
   - If interested, provide consent for a follow-up interview. If selected, participate in follow-up interview (estimated 45 minutes)
   - provide feedback on the analysis and findings of the interview if you participate
   - The initial questionnaire is estimated to take 15 minutes to complete. Participants in the follow-up interview will be scheduled for 45 minutes. The interview will happen virtually through the Zoom platform.
   - You can complete the survey and choose to not participate in the interview

3. Are there any experimental medical treatments?
   No

4. Is there any risk to me?
   Possible risks or sources of discomfort include: Participants may experience mild
discomfort or anxiety when reflecting upon past mathematical experiences. If you
experience discomfort, you have the right to withdraw at any time or choose to skip
questions. If you become upset and wish to speak with someone, you may speak with
Kyle Brun or Merry Staulter. If you experience discomfort, you have the right to
withdraw at any time.

Participants will provide identifiable information in the initial survey and, if applicable,
video and audio recordings will be collected during the interview process. To protect
participant identity, participant information from the survey will anonymized. Individuals
who volunteer for the phase 2 interview will use a pseudonym and will be reminded to
not including identifiable data in responses. Following data analysis all recordings and
e-mail communications will be deleted. No identifiable data will be included in any
publication or future presentation.

5. Is there any benefit to me?
Benefits to you may include: Participants may gain a deeper understanding of how
their mathematical identities influence their teaching practices and may help them
identify ways to foster positive mathematical identities in their students. Other benefits
may include: The information provided by the study will help school leaders and
teachers recognize instructional strategies that may promote or prevent the
development of a positive mathematical identity in students. Furthermore, a deeper
understanding of how teachers’ mathematical identities influence their teaching
practices may help districts develop and provide targeted professional development to
their staff.

6. How will you protect my privacy?
Audio and visual recordings of the interview sessions will be created. The follow-up
interviews will be conducted virtually through Zoom. A recording of the audio and
visual Zoom interview will be maintained for the purpose of transcription. Once
transcripts are created and checked for accuracy, the researcher will delete the
recordings of the interview. All identifiable information will be removed during
transcription. Your records will be private. Only Kyle Brun (PI), Dr. Merry Staulter (WCU
Faculty Advisor), Dr. Brian Bowen (WCU Faculty), and the IRB will have access to your
name and responses.

How will records will be stored: Password Protected File/Computer Data will be stored
on password-protected devices and servers. When imported into Statistical Package for
the Social Sciences (SPSS) for analysis, the data will be coded and randomized to
remove any identifiable information. Identifiable data will only be maintained until
interview participants are identified and scheduled. Following the transcription of the interviews, all identifiable data will be coded or destroyed. Video/audio recordings will be erased following transcription. Records will be destroyed Three Years After Study Completion.

7. Do I get paid to take part in this study?
   No

8. Who do I contact in case of research-related injury or if I have questions about the study?
   For any questions about this study, contact: Primary Investigator: Kyle Brun at 484-574-7208 or kb985201@wcupa.edu and/or Faculty Sponsor: Merry Staulter at 610-436-2398 or mstaulter@wcupa.edu

9. What will you do with my Identifiable Information?
   Your information will not be used or distributed for future research studies.

For any questions about your rights in this research study, contact the ORSP at 610-436-3557.

If you agree to participate, you are agreeing to the following statement;

I have read this form and I understand the statements in this form. I know that if I am uncomfortable with this study, I can stop at any time. I know that it is not possible to know all possible risks in a study, and I think that reasonable safety measures have been taken to decrease any risk.

If you agree to participate, check, “YES, I agree to participate” and you will be directed to the survey. If you do not agree to participate, check, “NO, I do not agree to participate” and you will be directed to the end of the survey where you may exit.

This study has been approved by the West Chester University Institutional Review Board, IRB number: IRB-FY2023-360.

- Yes, I consent to participate
- No, I do NOT wish to participate
## Appendix G: Frequency Results for Survey Items

<table>
<thead>
<tr>
<th>Survey Section 1</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td><strong>I enjoyed math class when I was in school.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I enjoyed math class when I was in school.</td>
<td>4</td>
<td>8.3%</td>
<td>16</td>
<td>33.3%</td>
<td>3</td>
</tr>
<tr>
<td><strong>I believe that I am good at math.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I believe that I am good at math.</td>
<td>7</td>
<td>14.6%</td>
<td>5</td>
<td>10.4%</td>
<td>0</td>
</tr>
<tr>
<td><strong>I believe that math is useful in my daily life.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I believe that math is useful in my daily life.</td>
<td>0</td>
<td>0%</td>
<td>0</td>
<td>0%</td>
<td>0</td>
</tr>
<tr>
<td><strong>I believe that solving math problems quickly is important.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I believe that solving math problems quickly is important.</td>
<td>3</td>
<td>6.3%</td>
<td>9</td>
<td>18.8%</td>
<td>7</td>
</tr>
<tr>
<td><strong>I believe that getting the right answer is the most important thing in math.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I believe that getting the right answer is the most important thing in math.</td>
<td>5</td>
<td>10.4%</td>
<td>13</td>
<td>27.1%</td>
<td>8</td>
</tr>
<tr>
<td><strong>I believe that my math education was effective.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I believe that my math education was effective.</td>
<td>3</td>
<td>6.3%</td>
<td>10</td>
<td>20.8%</td>
<td>8</td>
</tr>
<tr>
<td><strong>I enjoy teaching math.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I enjoy teaching math.</td>
<td>0</td>
<td>0%</td>
<td>3</td>
<td>6.3%</td>
<td>1</td>
</tr>
</tbody>
</table>
I am confident in my mathematical abilities as an educator.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>0</td>
<td>0%</td>
<td>3</td>
<td>6.3%</td>
<td>2</td>
</tr>
</tbody>
</table>

I was a good math student in school.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>2</td>
<td>4.2%</td>
<td>6</td>
<td>12.5%</td>
<td>8</td>
</tr>
</tbody>
</table>

I can understand even the most difficult mathematical concepts.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>9</td>
<td>18.8%</td>
<td>14</td>
<td>29.2%</td>
<td>14</td>
</tr>
</tbody>
</table>

I am interested in mathematics.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>0</td>
<td>0%</td>
<td>6</td>
<td>12.5%</td>
<td>10</td>
</tr>
</tbody>
</table>

I like to learn new ways to solve math problems.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>2</td>
<td>4.2%</td>
<td>0</td>
<td>0%</td>
<td>7</td>
</tr>
</tbody>
</table>

Survey Section 2

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>I believe that some people just don't get math.</td>
<td>12</td>
<td>25.0%</td>
<td>17</td>
<td>35.4%</td>
</tr>
</tbody>
</table>

I believe that some people are born with brains that work in ways that are just better for math and science.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>7</td>
<td>14.6%</td>
<td>4</td>
<td>8.3%</td>
<td>9</td>
</tr>
</tbody>
</table>
I believe that it is important that people are able to explain their reasoning in math.

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>1</td>
<td>2.1%</td>
<td>1</td>
<td>2.1%</td>
<td>6</td>
<td>12.5%</td>
</tr>
</tbody>
</table>

I believe that people see value in what they learn in math class.

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>1</td>
<td>2.1%</td>
<td>5</td>
<td>10.4%</td>
<td>4</td>
<td>8.3%</td>
</tr>
</tbody>
</table>

I believe that the concepts people learn in math class are vital to their success in life.

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>0</td>
<td>0%</td>
<td>1</td>
<td>2.1%</td>
<td>4</td>
<td>8.3%</td>
</tr>
</tbody>
</table>

---

Survey Section 3

I believe that it is my responsibility to build my students' beliefs that they are good at math.

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>0</td>
<td>0%</td>
<td>0</td>
<td>0%</td>
<td>0</td>
<td>0%</td>
</tr>
</tbody>
</table>

I like to teach using the same strategies that I was exposed to as a math student.

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>6</td>
<td>12.5%</td>
<td>11</td>
<td>22.9%</td>
<td>13</td>
<td>27.1%</td>
</tr>
</tbody>
</table>

I believe that expectations for math instruction have changed throughout my career.

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree nor Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>1</td>
<td>2.1%</td>
<td>1</td>
<td>2.1%</td>
<td>0</td>
<td>0%</td>
</tr>
</tbody>
</table>
I prefer instructional strategies that maximize collaborative problem solving.

| 0  | 0%  | 5  | 10.4% | 13 | 27.1% | 17 | 35.4% | 13 | 27.1% |

I believe that students learn best when they engage in discussions about problem solving.

| 0  | 0%  | 5  | 10.4% | 4  | 8.3%  | 12 | 25.0% | 27 | 56.3% |

I believe that feedback on how students engage with math problems that is not centered on the final answer is valuable.

| 0  | 0%  | 0  | 0%   | 6  | 12.5% | 18 | 37.5% | 24 | 50.0% |
Appendix H: Letters of Support from Participating Districts

Date: September 1, 2023

West Chester University Institutional Review Board
West Chester University
700 South High Street
West Chester, PA 19383

Dear Members of the Institutional Review Board,

Kyle Brun (IRB NUMBER: IRB-FY2023-360) has permission to conduct his/her research on The Manifestation of Elementary Teachers’ Mathematical Identity a Mixed Methods Case Study in Sunnyside Elementary School, Indian Stone Elementary School, Media Elementary School, and Rose Tree Elementary School in the Rose Tree Media School District. I have been advised of the purpose and scope of the research and how the data will be collected. I also understand that all information and data will be collected and stored in a confidential and appropriate manner.

The research will be conducted between September 1, 2023 and June 30, 2024. Participants include elementary math teachers with at least one year of teaching experience. I understand permission is contingent upon approval from West Chester University’s Institutional Review Board.

The person responsible for distributing recruitment materials

Name: Dr. Andrew Coonradt
Contact Information: coonradt@wchsa.edu or 410-629-0933

Sincerely,

William M. Dougherty

Children First, . . . Always!
Date: September 1, 2023

West Chester University Institutional Review Board
West Chester University
700 South High Street
West Chester, PA 19383

Dear Members of the Institutional Review Board,

Kyle Brun (IRB NUMBER: IRB-FY2023-360) has permission to conduct his/her research on The Manifestation of Elementary Teachers’ Mathematical Identity a Mixed Methods Case Study at
Elementary School, Ramrod Elementary School, and Wayne Elementary School in the Ramrod Township School District. I have been advised of the purpose and scope of the research and how the data will be collected. I also understand that all information and data will be collected and stored in a confidential and appropriate manner. The research will be conducted between September 1, 2023 and June 30, 2024. Participants include elementary math teachers with at least one year of teaching experience. I understand permission is contingent upon approval from West Chester University’s Institutional Review Board.

The person responsible for distributing recruitment materials

Name: Shawn Dutkiewicz
Email: Shawn.Dutkiewicz@west Chester.edu
Phone: 610-693-8100 x6141

Sincerely,

Dr. Shawn Dutkiewicz
Date: August 09, 2023

West Chester University Institutional Review Board
West Chester University
700 South High Street
West Chester, PA 19383

Dear Members of the Institutional Review Board,

Kyle Brun (IRB NUMBER: IRB-FY2023-360) has permission to conduct his/her research on The Manifestation of Elementary Teachers’ Mathematical Identity a Mixed Methods Case Study at Aston Elementary, Brookhaven Elementary School, Pennal Elementary School, and Parkside Elementary School in the Penn-Debo School District. I have been advised of the purpose and scope of the research and how the data will be collected. I also understand that all information and data will be collected and stored in a confidential and appropriate manner. The research will be conducted between September 1, 2023 and June 30, 2024. Participants include elementary math teachers with at least one year of teaching experience. I understand permission is contingent upon approval from West Chester University’s Institutional Review Board.

The person responsible for distributing recruitment materials

Name: Danielle Murray

Contact Information: Danielle.Murray@wcu.edu, 610-436-3093 ext. 352

Sincerely,

[Signature]
Eric Kim Nikola, Assistant Superintendent

Proudly serving the communities of Aston, Brookhaven, and Parkside.
Date: September 13, 2023

West Chester University Institutional Review Board
West Chester University
700 South High Street
West Chester, PA 19383

Dear Members of the Institutional Review Board,

Kyle Brun (IRB NUMBER: IRB-FY2023-360) has permission to conduct his/her research on The Manifestation of Elementary Teachers' Mathematical Identity a Mixed Methods Case Study at Gilbertson ES, Locust ES, Russell ES, and Worrell ES in the Marple Newtown School District. I have been advised of the purpose and scope of the research and how the data will be collected. I also understand that all information and data will be collected and stored in a confidential and appropriate manner. The research will be conducted between September 1, 2023 and June 30, 2024. Participants include elementary math teachers with at least one year of teaching experience. I understand permission is contingent upon approval from West Chester University’s Institutional Review Board.

The person responsible for distributing recruitment materials

Name: Joel DiBartolomeo

[Contact Information]

Sincerely,

Joel DiBartolomeo
Assistant Superintendent
Date: September 7, 2023

West Chester University Institutional Review Board
West Chester University
700 South High Street
West Chester, PA 19383

Dear Members of the Institutional Review Board,

Kyle Brun (IRB NUMBER: IRB-FY2023-360) has permission to conduct his/her research on The Manifestation of Elementary Teachers’ Mathematical Identity a Mixed Methods Case Study at Logan Elementary, Greenwood Elementary, and New Garden Elementary in the Kenwood Consolidated School District. I have been advised of the purpose and scope of the research and how the data will be collected. I also understand that all information and data will be collected and stored in a confidential and appropriate manner. The research will be conducted between September 1, 2023 and June 30, 2024. Participants include elementary math teachers with at least one year of teaching experience. I understand permission is contingent upon approval from West Chester University's Institutional Review Board.

The person responsible for distributing recruitment materials

Name: [Redacted]

Contact Information: [Redacted]

Sincerely,

[Signature]

Learn. Apply. Achieve.
Date: August 28, 2023

West Chester University Institutional Review Board
West Chester University
700 South High Street
West Chester, PA 19383

Dear Members of the Institutional Review Board,

Kyle Brun (IRB NUMBER: IRB-FY2023-360) has permission to conduct his/her research on The Manifestation of Elementary Teachers’ Mathematical Identity a Mixed Methods Case Study. The research includes travel to Upland Elementary, Hilltop Elementary, Fairwood Elementary, and Upper High Elementary in the Upper High School District. I have been advised of the purpose and scope of the research and how the data will be collected. I also understand that all information and data will be collected and stored in a confidential and appropriate manner. The research will be conducted between September 1, 2023, and June 30, 2024. Participants include elementary math teachers with at least one year of teaching experience. I understand permission is contingent upon approval from West Chester University’s Institutional Review Board.

The person responsible for distributing recruitment materials

Name: Diana Hanbeck
Contact Information: dhanbeck@wichester.edu

Sincerely,

[Signature]

Dr. Daniel G. Nerelli
Superintendent of Schools
Date: June 1, 2023

West Chester University Institutional Review Board
West Chester University
700 South High Street
West Chester, PA 19383

Dear Members of the Institutional Review Board,

Kyle Brun has permission to conduct his/her research on The Manifestation of Elementary Teachers’ Mathematical Identity a Mixed Methods Case Study at Garnet Valley Elementary School, Concord Elementary School, and Bethel Springs Elementary School Agency in the Garnet Valley School District. I have been advised of the purpose and scope of the research and how the data will be collected. I also understand that all information and data will be collected and stored in a confidential and appropriate manner. The research will be conducted between September 1, 2023 and June 1, 2024. Participants include elementary math teachers with at least three years of teaching experience. I understand permission is contingent upon approval from West Chester University’s Institutional Review Board.

Sincerely,

Dr. Marc Bertrand
Superintendent of Schools

The person responsible for distributing recruitment materials
Name: Leslie Brun or Leslie Hutchinson
Contact Information: buck@garnetvalley.org
hutch@garnetvalley.org
September 6, 2023

West Chester University Institutional Review Board
West Chester University
700 South High Street
West Chester, PA 19383

Dear Members of the Institutional Review Board,

Kyle Brun (IRB NUMBER: IRB-FY2023-360) has permission to conduct his/her research on The Manifestation of Elementary Teachers’ Mathematical Identity a Mixed Methods Case Study at three London Elementary School and Avon Grove Intermediate School in the Avon Grove School District. I have been advised of the purpose and scope of the research and how the data will be collected. I also understand that all information and data will be collected and stored in a confidential and appropriate manner.

The research will be conducted between September 1, 2023 and June 30, 2024. Participants include elementary math teachers with at least one year of teaching experience. I understand permission is contingent upon approval from West Chester University’s Institutional Review Board.

Respectfully,

M. Christopher Marchese Ed.D.
Superintendent of Schools