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Factors Influencing Elementary Mathematics Teachers' Beliefs in Reform-Based Teaching

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I investigated a reform based teachers' beliefs about the nature of mathematics, teaching mathematics, and learning mathematics, and the factors leading to their formation. I interviewed and observed a reform-based elementary mathematics teacher with 13 years' experience teaching first grade. She held a Platonist/problem solver view of mathematics, explainer view of teaching, and an active view of learning and was influenced by her husband, preschool son, past teachers, certification, professional development, and teaching experience. I found personal factors outside of education could significantly support beliefs in reform-based teaching and speculate that reflection on personal factors could initiate belief change.

The National Council of Teachers of Mathematics (NCTM, 1989) contributed to a reform movement to address the failures in schools to meet students' mathematical needs. NCTM called for reform-based teaching practices promoting numerous and varied interrelated experiences that encourage students to value mathematics (NCTM, 1989). The Common Core State Standards (2010) supported this movement stating, "It is time for states to work together to build on lessons learned from two decades of standards-based reforms. It is time to recognize that these standards are not just promises to our children, but promises we intend to keep" (p. 1).

To keep this promise, teachers must implement reform-based practices, yet NCTM (2014) explained many teachers still do not implement these practices because they clash with their previous beliefs about education formed from their experiences as learners. Teachers implement practices in their classrooms if they align with their belief structures (Philipp, 2007). Fives and Buehl (2016) explained research in reform-

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based mathematics education reinforces the need to study the development of teachers' beliefs because the teachers are resistant to reform-based practices. Fives and Buehl believed understanding belief development could help guide teachers' decision-making process in the classroom and provide more targeted feedback to support professional growth and development for teachers. Therefore, in this investigation I studied a reform-based teacher to determine what factors contributed to her sustainable belief change in mathematics.

Influencing Factors on Beliefs

In a chapter in the *Handbook of Research on Teacher Education*, Richardson (1996) identified the following factors that affect beliefs (see Figure 1): (a) personal experiences (past and present events that occurred outside of school), (b) experience with schooling and instruction (past and present events that occurred in K-16 schools), and (c) experience with formal knowledge (past and present development of knowledge). The current research investigating beliefs can still be categorized in this manner.

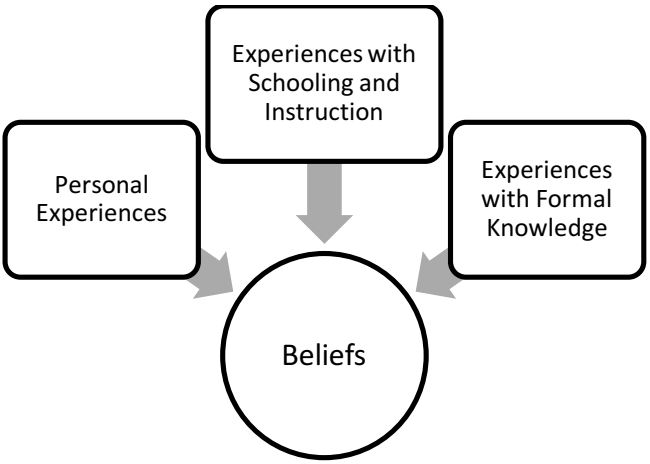

Figure 1. Richardson's (1996) factors affecting belief change

Personal Experiences

Many researchers investigated the influence of personal experiences on beliefs (Clandinin, 1986; Clanindin & Connelly, 1991). Teachers' personal histories were shown to influence their understanding of society and culture (Clandinin, 1986; Clanindin & Connelly, 1991). Levin and He (2008) and Raymond (1997) found preservice teachers attributed their pedagogical belief development to their family background and personal experiences.

Literature from counseling, social work, and psychology explore the relationship between individuals' family lives and their career choices, and through this literature, researchers found that it is important to look at personal, family, and home relationships as a serious and formative source of beliefs (Leifman, 2001; Stewart, Coll, & Osguthorpe, 2013; Zimmerman & Cochran; 1993). Leifman (2001) and Zimmerman and Cochran (1993) found many individuals' immediate family background and the roles people play in their family transferred to their careers. Stewart et al. (2013) investigated the social and emotional influence of family dynamics on teachers, and she found a connection with individuals' family backgrounds and their teaching practices. Yet in these investigations, the researchers did not look into the influence on belief development.

Thomson and Kehily (2011) investigated first-time mothers' transition through the workforce. These mothers came from various careers including child care providers and education. As a result of the birth of their first child, individuals' behaviors changed, and they reevaluated their treatment of their own students based on what they had learned from having their own child (Thomson & Kehily, 2011). "Becoming a mother prompted a renegotiation of professional and personal boundaries in which new modes of identification and desire emerged, including the desire for a particular class trajectory for their own child" (Thomson & Kehily, 2011, p. 244). This study supports the idea that mathematics educators might fruitfully examine whether the fact of having children

influences teachers' relationships with and beliefs about their students.

Experience with Schooling and Instruction

Many researchers investigated the second factor consisting of the teacher's experience as both student and teacher (Anning, 1988; Banilower et al., 2006; Britzman, 1991; Weiss & Pasley, 2004). Anning (1988) and Britzman (1991) identified teachers' classroom teaching experiences as a determining factor in the development of individual beliefs. Banilower et al. (2006) and Weiss and Pasley (2004) found that a traditional lesson paradigm is still prevalent in many schools because of teachers' past experiences as students in traditional classrooms.

Teachers' beliefs about student learning created by their own learning experience affect the formation of other beliefs (Richardson, 1996). Dewey's (1938) theory of experience exemplifies how students' experiences can influence their learning process, and teachers' views on students' learning influence beliefs about the teacher's role in mathematics classrooms. Dewey defined experience as an event a person undergoes, but not all events were identified as educative or genuine. He stated,

> Everything depends upon the quality of the experience, which is had. The quality of any experience has two aspects. There is an immediate aspect of agreeableness or disagreeableness and there is its influence upon later experiences (Dewey, 1938, p. 27).

He claimed that if students were engaged in an event it would help to further their knowledge. These students became teachers whose prior school experiences influenced their views on learning.

Research has shown that teacher education programs and professional development programs can influence belief change through various activities (Ambrose et al., 2004; Cooney, Shealy, & Arvold, 1998; Mewborn & Stinson, 2007;

Philipp et al., 2007; Richardson, 1996; Stuart & Thurlow, 2000; Swars et al., 2007). Teachers using Cognitively Guided Instruction were found to change beliefs (Philipp et al., 2007). Also, Ambrose et al. (2004) investigated how preservice teachers' beliefs changed after investigating invalid teaching practices. Yet, the main commonality across this research was the use of reflection to initiate individuals' contemplation of conflicting beliefs (Ambrose et al., 2004; Kagan, 1992; Philipp et al., 2007; Stuart & Thurlow, 2000). For example, instructors could ask their preservice teachers to write in journals or construct autobiographies to reflect on why they believe in certain teaching practices while they hold different beliefs about student learning (Stuart & Thurlow, 2000).

Levin and He (2008) and Raymond (1997) found preservice teachers attributed their pedagogical belief development also to their teacher education courses and experiences observing practicing teachers. Raymond (1997) found inservice teachers attributed their pedagogical belief development to their teacher education program, family values and experience, teaching experiences, recent professional development, and observing other teachers. However, neither Levin and He (2008) nor Raymond (1997) discussed the influence of participants' children and partners on their development of beliefs.

Experiences with Formal Knowledge

Many researchers investigated the third factor of experience with formal knowledge (Ball & Forzani, 2009; Ball, Thames, & Phelps, 2008; Crow, 1987; Raymond, 1997). Pedagogical knowledge gained from educational programs or teaching experience affected teachers' beliefs (Crow, 1987). Ball and Forzani (2010) and Ball, Thames, and Phelps (2008) suggested that there is specialized expertise and professional knowledge for teaching that help support effective teaching practices. However, Richardson (1996) found that experiences with formal pedagogical knowledge are seen as the least powerful factor affecting beliefs.

Belief Framework

I used Philipp's (2007) formal definition of beliefs as "psychologically held understandings, premises, or propositions about the world that are thought to be true" (Philipp, 2007, p. 259). To describe my participant's beliefs about reform-based teaching, I employed Ernest's (1989) belief framework. Ernest described three forms of beliefs: beliefs about the nature of mathematics, beliefs about teaching mathematics, and beliefs about learning mathematics. Ernest (1989) stated that there were three views of the nature of mathematics: the instrumentalist view, the Platonist view, and the problem solving view. Teachers with an instrumentalist view believed mathematics to be a set of rules and procedures. Teachers with the Platonist view believed mathematics to be a unified, unchanging body of knowledge. Teachers with the problem solving view believed mathematics to be a man-made creation that is continually expanding. These three beliefs about the nature of mathematics were found by Ernest to have significant correlation to teachers' beliefs about mathematics teaching, but they are not mutually exclusive.

The three categories identified by Ernest as beliefs about mathematics teachers' roles were instructor, explainer, and facilitator. Ernest described instructors as individuals who had a "narrow, instrumental and basic skills type view" (Ernest, 1989, p. 11). The mathematics teachers who were classified as explainers believed in developing students' conceptual understanding of mathematical concepts. Ernest described facilitators as teachers who believed in using problem solving in their classrooms to teach students to reason mathematically.

Ernest also identified two teacher views on student learning: passive recipients of knowledge or active constructers of knowledge. Ernest (1989) suggested that individuals who held a Platonist view of mathematics would be more likely to enact an explainer's role in the classroom and view learners as passive recipients of knowledge. Ernest (1989) explained, "These three philosophies of mathematics, as psychological systems of belief, can be conjectured to form a hierarchy" (p.

250). In this view, instrumentalism is the lowest level and the problem solving view is the highest.

It must be noted that just because teachers espouse or claim to believe a certain idea does not necessarily mean it was enacted in their classroom practices (Cooney, Shealy, & Arvold, 1998). Individuals often are not aware of their beliefs, so researchers must interpret participants' understanding using multiple strategies to ensure an accurate representation of their views (Cooney, Shealy, & Arvold, 1998). If researchers find contradictory beliefs, they need to assume the inconsistencies exist in their minds. As Leatham (2006) stated,

> When a teacher acts in a way that is consistent with the beliefs we have inferred, we have evidence that we may be on track, but we do not know what belief or beliefs the teacher was actually acting on at the time. When a teacher acts in a way that seems inconsistent with the beliefs we have inferred, we look deeper, for we must have either misunderstood the implications of that belief, or some other belief took precedence in that particular situation. (p. 95)

If we have accurately interpreted teachers' beliefs, they may have beliefs about other demands that overshadow their views of mathematical teaching practice (Leatham, 2006). Therefore, as long as other demands do not interfere, teachers' beliefs could influence teachers' classroom practices. I was mindful of Leatham's claim that teachers' beliefs were a sensible system and deliberately sought to discover other beliefs that participants may have held that did not pertain directly to the teaching and learning of mathematics.

To understand the range of beliefs an experienced/reform-based mathematics teacher might have and the factors that influenced those beliefs, I investigated the following research questions:

1. What were the current beliefs about the nature of mathematics, teaching mathematics, and learning

mathematics of an elementary teacher who implemented reform-based practices?
2. What factors contributed to the formation of these beliefs?

Methods

The data from this investigation were collected over a two-month period. Using methodological triangulation from three interviews, one survey, and three classroom observations focusing on the participant's teaching style, I was able to infer her beliefs and identify the influences affecting this teacher's practices.

Participants

One participant was investigated for this study. Mary was an African-American teacher with thirteen years of experience teaching in first grade. Mary was selected because she was a current elementary teacher with at least ten years of experience implementing reform-based mathematics practices in her classroom. I drew from the NCTM's (1989) recommendations to define reformed teaching practices as practices supporting students having multiple experiences to investigate mathematics, construct mathematical habits of mind, and appreciate mathematics in the real world. Mary's principal identified her as a reform-based teacher. Additionally, I conducted personal observations of Mary's classroom teaching prior to the investigation to determine her fit with the goals of my study.

Data Collection

I investigated my research questions using a case study design. As deMarrais & Lapan (2005) explained, "a major strength of case studies is the opportunity to use many different sources of data" (p. 228). As seen in Table 1, I provided triangulation by conducting three face-to-face interviews, three classroom observations, and Shiver's (2010) Mathematical

Belief Survey, which is a 50-question paper and pencil, Likert scale survey.

Table 1

Data Collection Timeline

Month	Sequence	Research Task
September	1	Conducted initial interview.
	2	Conducted initial classroom observation.
	3	Mary took the Shiver's (2010) Mathematical Belief Survey.
	4	Analyzed results of Shiver's (2010) Belief Survey.
November	5	Conducted second interview.
	6	Conducted second classroom observation.
	7	Analyzed second interview.
January	8	Conducted third classroom observation.
March	9	Analyzed all the data and constructed my interpretation of Mary's beliefs and factors affecting beliefs.
May	10	Emailed Mary my interpretation of her data.
	11	Conduct the final interview based on her responses to my interpretations.

For the three interviews, I used a form of the interview guide approach (Patton, 2002). For the first interview, I used a stimulus text to prompt responses. I gave six questions, each related to the individual's mathematical beliefs. The first two questions were created using works from Cooney, Shealy, and Arvold (1998) and the last four questions were created using the Integrating Mathematics and Pedagogy (IMAP) Belief Survey (Philipp et al., 2007). Because most individuals are not aware of their beliefs (Cooney, Shealy, & Arvold, 1998; Thompson, 1992), Cooney, Shealy, and Arvold created similes to help stimulate discussion about beliefs about mathematics that I adopted in my first interview to help Mary talk about her beliefs. For example, I asked Mary to complete the sentences "Learning mathematics is like _____. A mathematics teacher is like _____" (adapted from Cooney, Shealy, & Arvold, 1998). As Cooney et al. suggested, I interpreted the

participant's beliefs from her explanations of each simile rather than just her answer to the questions (Cooney, Shealy, & Arvold, 1998). The last four questions from the first interview were items from the IMAP Belief Survey (Philipp et al., 2007). The survey is a web-based survey including video clips, open response questions, and written teaching episodes. Mary's responses were scored with a rubric to assess her beliefs about the nature of mathematics, teaching mathematics, and learning mathematics (Philipp et al., 2007). For the purpose of this study, all four questions used in the first interview came from the open response portion of the IMAP survey.

In the second interview, I used open-ended questions and directed questions to determine influences on Mary's mathematical beliefs. For example, I asked,

- You stated that your father was a big influence in your life. Could you describe what kind of teacher your father was?
- You expressed that your previous teachers had a large impact on your teaching style. Could you name a specific teacher and describe her or him to me?

While answering questions in the first interview, Mary alluded to events and people who helped her construct her personal understanding of the nature of mathematics, teaching mathematics, and learning mathematics. I used open-ended questions to allow her the opportunity to explain what she meant by those responses.

For the final interview I used a stimulus text to create a member check. By giving Mary a written draft of the data, I was able to confirm the validity of my findings with my participant.

Data analysis

The analysis process consisted of three parts. First, the interviews were transcribed and the survey and field notes were typed for analysis. Second, the data were coded and analyzed for the participant's belief development. I coded the field notes,

the transcripts of the interviews, and the results of the Shiver's (2010) Belief Survey by identifying evidence supporting Mary's beliefs about the nature of mathematics, beliefs about teaching mathematics, and beliefs about learning mathematics, as seen in Table 2. Third, I analyzed the codes for patterns and categorized Mary's beliefs using Ernest's (1989) framework. As a member check, I gave Mary a narrative describing her beliefs and the influences on them and asked her to give her feedback. She stated,

> Reading through it, I remember saying all this, so it is pretty accurate. I really like the way you put everything in print, and I think it pretty much accurately describes my teaching beliefs and the way I, you know, conduct my class with my students.

Table 2
Coding Method

Code	Characteristic	Example	Analysis
Belief about the Nature of Mathematics	When the participant describes how they view how mathematics is structured.	The main objective of the study of mathematics is to develop reasoning skills that are necessary for solving problems	Problem Solving
Belief about Mathematics Teacher's Role	When a participant describes how mathematics teacher should teach concepts to their students.	I like to model different ways of approaching things, so if I have them figure out different ways to decompose numbers, I will say here are some examples.	Explainer
Belief about Mathematics Learning	When a participant describes how students should learn mathematics concepts.	Students must work and struggle through the problems to understand and learn the concepts.	Active Construction of Knowledge

Findings

In this section, I present Mary's beliefs profile to describe her current beliefs about the nature of mathematics, teaching

mathematics, and learning mathematics. I conclude this section with a description of the factors she identified as influencing the construction of these beliefs.

Mary's Overarching Beliefs

Mary had an overarching belief that she should help students reach their full potential. She explained, "I always want to help them to see their potential—where they can go and how can they make it better." She explained in her interview how she implemented this belief in her classroom by using differentiation. Mary scaffolded her students' understanding by offering multiple question types depending on the student's needs.

Mary's Belief About Mathematics

Mary's view of mathematics was between Ernest's classification of a problem solver and Platonist, as seen in Table 3. Mary believed mathematics had a given structure and, as a first grade teacher, it was her job to set the foundation for other skills taught in later grades. She explained, "In math, it's kind of like building a house because you have to teach first graders to make sure they can identify numbers, then put numbers together with adding and subtracting" (Interview 1). However, she agreed in her belief survey that "mathematics is continually expanding its content and undergoing changes to accommodate new developments" and "the main objective of the study of mathematics is to develop reasoning skills that are necessary for solving problems" (Belief Survey). During her third interview, she explained that she believed "the sky is the limit for mathematics; it never ends" for her students' mathematical understanding (Interview 3).

Table 3
Mary's Beliefs Classified Using Ernest's (1989) Framework

Classification	Mary's Beliefs
Belief about the Nature of Mathematics	Platonist/Problem Solver
Belief about Mathematics Teacher's Role	Explainer
Belief about Mathematics Learning	Active Construction of Knowledge

Although some of her statements seemed to imply Mary held a Platonist view of mathematics, others indicated she also held problem solving beliefs. Mary's mathematics classroom centered on problem solving. Mary started off each lesson with a problem solving activity where students had to come up with multiple ways to represent the number of the day. For example, she would give them the number 27 and the students were asked to represent that number in as many ways as possible. Then she would bring the class together for a number talk featuring the students' representation of the value as a number sentence, as the result of a word problem, as a combination of coins, or with pictures (Observation 3). Once she began her lesson, I was able to observe her students using their problem solving strategies to create their understanding of place value and addition. One lesson had the students playing a game creating their own addition problems by rolling two dice, but she had them construct two different ways of determining the combined values on the dice. Students typically either used their understanding of counting by 2 or created a word problem that they represented with a picture to display the value (Observation 1). She believed mathematics was man-made and can be explained, but there is a structure of knowledge she must build.

Mary's Belief About Mathematics Teaching

Mary adhered to what Ernest (1989) called an explainer's role in the classroom. She believed the goal of instruction was for students to develop concepts as a result of her modeling. She viewed mathematics teachers as coaches: "You are coaching them. You are showing them different strategies. You are showing ways that work" (Interview 1).

When she was asked about what process best facilitated teaching mathematics, she explained, "I like to model different ways of approaching things. . . . Modeling is a great way to get them on the path of doing those various activities" (Interview 1). She showed evidence of this belief in her teaching during her classroom observations. Before each of the activities, she gave the students examples of how to solve the problem. For

example, before having the students play the dice game, she demonstrated how to roll the dice and she showed multiple ways she was able to determine the values of the combined amounts on the two dice (Observation 1). Mary believed this teaching method helped students reach their potential. She explained, "You have kids that say, 'I'm bored.' So I would show them a different way and then ask them to 'Try it this way. Go with it. See how high you can go'" (Interview 2). Through this process, she helped motivate her students to try new things.

Mary's Belief About Mathematics Learning

Mary believed that for students to learn they must be actively engaged in problem solving. In our first interview, Mary explained that she liked to use manipulatives first to help students understand the concept before teaching them any standard way of solving the problem. Each table in her classroom had a bin of manipulatives that the students could use when they were working on problems. If the students needed the extra assistance, they would open up the bin and use unifix cubes or base ten blocks to help them solve the problems (Observation 2). Her view of learning was consistent with Ernest's category of children actively constructing knowledge. For example, when she began teaching place value, she explained,

> I have a bag of [written] numbers, and they randomly grab one and represent it with the base ten blocks. That would show me they had an understanding of how to break that number down, how to see the different places in the number, and how that number came to be. (Interview 1)

Mary also believed mathematics learning was different for each student. She explained, "If you can get the desired outcome, I am happy for whatever works best for you because people see math and numbers in all different ways" (Interview 3). She demonstrated her view of learning in her classroom through her activities. For example, at the beginning of each observation,

she gave her students a number of the day that they had to break down in any way possible (Observation 1, 2, and 3). She explained, "I will ask them, 'How many different ways can you make the number 10? You can draw pictures. You can make tally marks.' . . . I just want to see how they understand or make that number" (Interview 1). This daily practice showed her belief that students can construct their number sense.

Factors Influencing Mary's Beliefs

Family. Mary's mother, father, husband, and son significantly influenced her beliefs about mathematics. When Mary was first asked about what could have influenced her belief development, she talked about her father. Her father was a retired high school administrator, but he also taught high school mathematics. Mary had him as a teacher in ninth grade. She explained,

> He was a very creative teacher. He was very hands-on. I remember when I was younger seeing him making manipulatives or things for his students to work with and getting really excited about presenting it. . . . So I think just his excitement for the subject, the way he used to create different ways to get the students to learn, and how he made it fun for them was probably a big influence on the way I teach everything. (Interview 2)

Her father held a belief that students learn through hands-on activities, and Mary adopted this belief in her teaching. She showed evidence of this belief in her classroom practices. During the lessons I observed, her students were given and encouraged to use manipulatives, making each lesson a hands-on experience.

Even though Mary's mother was not an educator, she still played an important part in shaping her as a teacher. Her mother was a social worker, and she focused on foster children. Mary grew up helping and working with these students, and because of her interactions, she became more aware of different students' needs. She stated,

> I think it shaped the way I am towards other people, and the way I interact with my kids here. You know, I have some kids who may not come from the best background and may struggle for various reasons. Because of my mother's influence, I feel I am more empathetic towards their needs. (Interview 2)

The compassion her mother showed to other foster students helped form Mary's overarching belief in helping students meet their potential. In her mathematics teaching practices she showed evidence of her awareness of her students' various needs. For example, in her first observation, she gave students different worksheets depending on their ability level. In our post-observation interview, Mary stated, "I always try to stay in tune with the kids by looking at their facial reaction and body language" (Interview 2). She attributed the act of being "in tune" with her students to her mothers' influence.

Mary's husband influenced her belief about mathematics. She called him a "beautiful mind" because he thought in numbers and actively tried to find patterns (Interview 2). He even pursued solving mathematical theorems in his spare time. He was certified to teach high school mathematics, but he decided to leave the career because he realized he was not teaching the higher-level concepts that he loved. Mary's interaction with her husband influenced her to develop from Platonist beliefs to a combination of Platonist and Problem Solver beliefs. From her experiences in elementary school, she believed mathematics was as a static body of knowledge, yet through her discussions about mathematics with her husband, she was able to see how people can create their own understanding of mathematics. She stated, "When I was taking the survey, I was wondering what John would say" (Belief Survey). By observing her husband, she was able to see "the sky is the limit" for mathematical learning.

Mary stated her son was an influencing factor on her beliefs:

> He is a huge factor because he is in kindergarten now. My kids [current students] were where he is last year. I use him

> a lot to help figure out the kids who have fallen behind and strategies and things to use to help them. (Interview 2)

She practiced and learned from her son's responses. She also used her son to help test lesson plans for her class. Mary said,

> I use him as a guinea pig a lot. When I am making my lesson plans, he helps me figure out what my kids might have missed in kindergarten and figure out how to reintroduce the concepts now that they are in first grade. (Interview 2)

Her son personally influenced the way she views how to teach her students. By having a student at home similar to the ages of her students, she was able to investigate practices to best meet the needs of her students.

Past teachers. Mary stated that past elementary teachers directly influenced her beliefs about student learning. As a student, she loved school in first grade. She explained the teacher "made school fun and hands-on" (Interview 2). Mary's first grade teacher was only in her first or second year of teaching, but she was very compassionate. Mary explained, "I just remember learning a whole lot from her and just always wanting to do my best because I wanted to impress her" (Interview 2). Mary wanted her students to feel the same way and said that she still thought of her first grade teacher often.

Mary said that another teacher also reinforced this belief in making learning fun by doing the opposite. She explained that in fourth grade, "I remember that was the year I didn't like school, and I didn't do my best because I was terrified of her. . . . She kind of shamed you until you figured it out, which is so wrong" (Interview 2). Her fourth grade teacher taught her that learning mathematics needed to be fun and engaging for students to want to learn the subject. She explained, "That is one of the reasons I try to make school fun and try to make kids enjoy it" (Interview 2).

Certification. Mary said that her mathematics content and methods classes had little influence on her belief development. She explained, "It seemed like more a regular math 101 class.

It helped me improve my math skills, but I wish we could have had that component where we could have taught it to kids to see if it actually worked" (Interview 2). Because her mathematics content courses were taught in a style that did not align with her beliefs about student learning, she did not implement practices she experienced in her classroom. In her second interview, she further explained,

> With the teacher education program, I learned so much more from just actually doing it. That was the biggest influence in my change because how I understand things is by actually getting out there. You can sit and read books, write papers, read research, but until you actually do it, you don't know. (Interview 2)

Mary found her teaching experience to be more influential than her teacher education program. Yet, she did state that she had specific experiences, such as studying abroad, that shaped some aspects of how she teaches in her classroom. During her study abroad experience she did not have the opportunity to observe mathematics classrooms, but she did learn the importance of integrating mathematics with different subjects. For example, in her weather unit she integrated measuring temperature into her science lesson. She explained, "We talked about Fahrenheit and Celsius, how to measure it, and how to talk about negative numbers or numbers below zero" (Interview 1). Although she was not aware of her teacher education experience having an influence on her beliefs, her integration of subjects showed that it played some role in how she teaches.

Professional development. Mary took all four of the gifted endorsement courses offered by her county, and through this program she was able to reflect and reevaluate the way she viewed students' learning. She stated, "This course taught me how to differentiate for different levels" (Interview 2). Mary used this understanding in her classroom. For example, she gave each student a different mathematical question while transitioning from seatwork to an activity on the floor. The question varied from 3 + 5 to 14 + 12 (Observation 2). In

another observation, she created three versions of the same problem solving activity (Observation 3). Each task differed only by the difficulty of the numbers and difficulty of the vocabulary. By giving different activities, she was able to differentiate her instruction to meet each student's instructional needs without singling out one group for their differences. In the post observation interview, Mary explained, "Just because you are smart does not mean you should have to do extra work. I find more creative ways to present the information" (Interview 1). Throughout her interviews and observations, Mary carried a consistent theme of differentiation. She said she learned many new strategies from her professional development to help implement her overarching belief in making a difference for her students.

Teaching experience. Mary's teaching experience had a large impact on her mathematics teaching beliefs. She believed that through her teaching experience she learned about "patience, building relationships, and getting ready to learn" (Interview 1). When I asked her to describe her first years of teaching, she said that when she first started teaching,

> I went by the book. I noticed that some kids were still not getting it [the material], and some kids were ready to move on. The following year is when I decided to move things around and kind of include this aspect or this manipulative or this math game. (Interview 2)

When I asked her why she changed, she explained that she wanted all of her students to meet their full potential, and the best way to help them was by manipulating the written curriculum. She held internal authority to make these decisions for her students. She even called herself a "rebel." When I asked her what she meant, she stated, "I do tend to deviate a lot. . . . Even as I am calling them to the floor, I might just think, 'Oh, I have this great idea.' Then I will Google it and print it really quick" (Interview 1). From her teaching experience, Mary demonstrated her belief in having and exercising teacher autonomy.

Discussion

I found the reform-based teacher held a Platonist/problem solver view of mathematics, explainer view of teaching, and an active view of learning. This indicated a teacher does not need to be in Ernest's highest categorization of beliefs about the nature of mathematics, teaching mathematics, and learning mathematics to implement reform-based teaching practices. Ernest (1989) believed individuals with specific beliefs would indicate specific teaching practices, yet through this investigation, Mary demonstrated how different combinations of beliefs about mathematics could produce a teaching practice encouraging "varied interrelated experiences that encourage them to value the mathematical enterprise, to develop mathematical habits of mind, and to understand and appreciate the role of mathematics in human affairs" (NCTM, 1989, p. 5).

Second, Mary regarded her family, past teachers, her certification process, professional development, and her teaching experiences as contributing factors to the formation of her beliefs and reform-based teaching practices. The different factors Mary identified in her interviews can be mapped to Richardson's (1996) three factors: personal experience, experience with schooling and instruction, and experience with formal knowledge. Richardson's (1996) factors came from a review of literature on beliefs, and this study demonstrates how it can be enacted in practice. This indicated reform-based teachers were influenced by the same factors as other teachers, yet how these factors influenced the individuals differed.

Personal Experience

Mary's family contributed to the way she viewed the nature of mathematics, mathematics teaching, and mathematics learning. Her personal experiences created her overarching views of mathematics. This was consistent with the literature finding that teachers were influenced by their personal experiences (Clandinin, 1986; Connelly, 1991; Levin & He, 2008). Mary's mother influenced her central belief of helping students reach their potential. Mary's central beliefs resisted

change just as Doyle (1990) suggested. Mary's father influenced her belief about the mathematics teacher's role in the classroom, and her husband influenced her belief about the nature of mathematics. Her son contributed to how she viewed students' learning. Thomson and Kehily (2011) found children influenced teachers' behaviors, but Mary's case study identified how children could also influence belief development, which was not identified in the literature. From identifying Mary's personal experiences, I inferred her most influential beliefs.

Experience with Schooling and Instruction

Mary identified four separate factors involving schooling and instruction: her experiences with past teachers, her personal teaching experiences, her certification program, and her professional development activities. Because of negative experiences, she became open to new ideas to help students learn. She did not enjoy the repetition of algorithms and memorization of facts taught to her during her elementary years; thus, she rejected those practices in her classroom and implemented many reform-based activities. Banilower et al. (2006) and Weiss and Pasley (2004) found that teachers continued using the traditional lesson paradigm because of their past experiences, yet Mary rejected this paradigm because of the same experiences.

Mary's teaching experience gave her the opportunity to implement different techniques to see how children learn mathematics and how to teach mathematics most effectively, which was consistent with the findings of Anning (1998) and Britzman (1991). Even though she was instructed to use the written curriculum as a guide for instruction, she learned from her teaching experience to follow her students' mathematical development. As she explained, her experiences teaching in her classroom gave her more understanding about students' mathematical knowledge than the mathematical content or pedagogy courses she took in her teacher education program. She de-emphasized the importance of her certification process and professional development in her interviews. Richardson

(1996) stated, "It is speculated that these strong beliefs in combination with the salience of the real world of teaching practice, create conditions that make it difficult for preservice teacher education to have an impact" (p. 105). Mary's comments about her teacher education experience were consistent with Richardson's observations.

Experiences with Formal Knowledge

Because of the complex nature of formal knowledge, I saw its influence across many areas in Mary's life. Mary's pedagogical knowledge and content knowledge of mathematics did have an impact on her beliefs and teaching practices, but when she described this knowledge, she was unable to separate what she learned from where and when she learned it. Therefore, Mary's formal knowledge can be identified by events from the two previous factors. For example, Mary constructed her belief about the discipline of mathematics through her father's instruction, her husband's discussions, her teaching experience, and some mathematics content courses. Content and pedagogical knowledge needed more practice to develop understanding.

Scholarly Significance

Understanding Mary's belief development suggests important implications to the mathematics education community. First, the study implies that individuals' parents, spouses, and children can influence teaching beliefs and may be more influential to many teachers than their educational course work. Second, the study provides evidence supporting Richardson's (1996) mapping of factors influencing beliefs of reform-based teachers. Third, the study suggests that mathematics teacher educators and professional developers could use teachers' personal experiences with mathematics to help them reflect on their beliefs.

Personal Experiences Outside of Schooling are a Large Influence

Mary's spouse, family, and son were important factors influencing her belief development. Raymond (1997) identified these outside factors as having a slight influence on teaching practices, and Richardson (1996) identified personal experiences as influential. Researchers have found that parents can influence individuals' careers (Guyas, 2011), children can influence teachers' behavior (Thomas & Kehily, 2011), and personal factors influence teachers' beliefs (Levin & He, 2008). However, Mary's family was the main source from which she developed her views on teaching, learning, and mathematics, suggesting that personal factors outside of teaching and teacher education may be more influential than shown in previous research.

I recognize that this is a single case study of an individual who had many different family associations with mathematics; however, the fact that Mary's beliefs were so strongly rooted in her personal relationships suggests that others could also have a stronger understanding of the nature of mathematics from outside sources. Archer (2000) claimed that many elementary teachers have similar beliefs about mathematics. Since Mary had personal influences on her beliefs, other teachers could have this relationship as well.

Supporting Richardson's Mapping

As described in the discussion, the data in this study support the claim that beliefs of reform-based teachers can be mapped using Richardson's (1996) factors. Richardson's (1996) factors were constructed in a handbook chapter on known belief research, and the three factors were her interpretation of the categorization found in the literature. This study confirmed the utility of Richardson's framework because the data fit easily into the structure. Each of the factors Mary identified could be mapped into one of the three categories—personal experience, experience with schooling and instruction, and experience with formal knowledge—without any outliers

requiring new categories. Also, the categories brought out the unequal weight between personal and professional influences on Mary's beliefs. Mary was influenced by both her personal and professional life in significantly different ways, and the framework allowed me to investigate all aspects of Mary's life despite this imbalance. The data suggest that mathematics educators investigating mathematical beliefs and the factors influencing those beliefs could use Richardson's mapping to better understand how mathematical beliefs and influences are enacted.

Influencing Future Teachers

These findings provide professional developers and teacher educators with evidence of the importance of reflection to help implement reform-based teaching practices. Ernest (1989) stated that reflection plays a key role in the ways that teachers enact their beliefs in the classroom. Just as Mary reflected on how her husband, children, and father helped develop her view of mathematics, professional developers could have teachers work with their spouses, children, and friends to help them reflect on their beliefs. Although Mary's results indicated that outside events and individuals were significant to her beliefs, more research is needed to see how personal factors outside of teaching and teacher education could influence teachers' belief development and how we could use this knowledge to shape teachers' beliefs in reform-based teaching.

Conclusion

Through this study, I inferred the current beliefs about the nature of mathematics, teaching mathematics, and learning mathematics of an elementary school teacher who implemented reform-based practices and found factors contributing to the formation of these beliefs and practices. I found that personal factors outside of teaching and teacher education, such as a teacher's spouse and children, could significantly support beliefs in reform-based teaching. I speculate that teachers' friends and family could be seen as sources to be reflected on

to initiate belief change. By analyzing Mary's beliefs, we can see how other teachers' factors could affect belief change and how we can help future preservice teachers become aware of their beliefs to develop more productive beliefs.

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