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Elementary Mathematics Teachers' Beliefs and Practices: Understanding the Influence of Teaching in a STEAM Setting

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Influence of Teaching in a STEAM Setting

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DEDICATION

I would like dedicate this work to my loving husband and beautiful children. This endeavor has been a sacrifice for us all and is a true testament to the phrase "teamwork makes the dream work." Marcos, you make me want to be better. You encourage me, challenge me, and hold me up when I am down. I am so blessed that I get to do this life with you.

Max, Lily, and Sophia Kate, I hope that this accomplishment teaches you something about sacrifice and hard work. You have witnessed many late nights spent in front of the computer and summers spent in class. Know that you can accomplish anything, but any true accomplishment is hard-won and comes only after much discipline, work, and sacrifice. I love you three so much. This is for you!

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ABSTRACT

Many elementary mathematics teachers hold beliefs about the teaching and learning of mathematics and enact practices that are not aligned with the recommendations of reform efforts in the field of mathematics education (Stigler & Hiebert, 2009). For standards-based reform to gain any significant success, many teachers will have to alter the deeply held beliefs that they have about mathematics teaching and learning (Ellis & Berry, 2005). Given the role that teachers' beliefs about the nature of mathematics and mathematics teaching and learning play in their selection and enactment of instructional practices, it is essential to understand the influence that different school settings may have on developing and changing teachers' beliefs and practices. This research project investigated the enacted practices and beliefs about the teaching and learning of mathematics held by elementary mathematics teachers situated in a STEAM (Science, Technology, Engineering, Arts, Mathematics) school. The analysis of the data collected in this study revealed four major findings related to the enacted practices and beliefs about mathematics teaching and learning held by mathematics teachers situated in a STEAM setting. The analysis of the data collected in this study revealed four major findings. Namely, this study revealed: (1) Teachers in a STEAM school expressed similar and consistent beliefs about the teaching and learning of mathematics that are considered productive in light

of reform efforts. (2) Teachers in a STEAM school enacted divergent practices. (3) Teaching in a STEAM school strengthened teachers' beliefs about the importance of integration and connecting mathematics to real world. (4) Teaching in a STEAM school influenced teachers' enacted practices in relation to situating mathematics in the real world.

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CHAPTER 1

INTRODUCTION

Research has demonstrated that teachers' beliefs about the nature of mathematics and mathematics teaching and learning play a vital role in teachers' effectiveness and instructional decision-making, including the practices they enact (Ernest, 1989; Ball, 1991; Richardson, 1996; Fennema & Franke, 1992; Pajares, 1992; Thompson, 1992). The reform movement in mathematics education advocates student-centered instructional practices that prioritize inquiry, problem solving, understanding, and discourse (National Council for Teachers of Mathematics [NCTM], 2000; NCTM, 2014; Ma, 2010; Peressini, Borko, Romagnano, Knuth, & Willis, 2004). The beliefs that teachers hold about the teaching and learning of mathematics influence the instructional strategies they select and enact. Beswick (2012) suggests, "Beliefs related to specific aspects of the particular context in which a teacher is working can also influence which other beliefs are most influential in terms of shaping their practice in that context" (p. 129). This research project investigated the beliefs and enacted practices related the teaching and learning of mathematics held by elementary mathematics teachers situated in a STEAM (Science, Technology, Engineering, Arts, Mathematics) school. I pursued this study to gain an understanding of how elementary mathematics teachers positioned in a STEAM school view mathematics teaching and learning in an environment that supports reform-

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oriented practices through prioritizing science, technology, engineering, arts, and mathematics in a real world, problem-based, transdisciplinary approach to learning.

Standards-based Reform

The reform movement in mathematics education advocates student-centered instructional practices that prioritize inquiry, problem solving, understanding, and discourse.

Supporters of the reform movement envision classrooms in which students:

Have numerous and various interrelated experiences which allow them to solve complex problems; to read, write, and discuss mathematics; to conjecture, test, and build arguments about a conjecture's validity; to value the mathematical enterprise, the mathematical habits of mind, and the role of mathematics in human affairs; and to be encouraged to explore, guess, and even make errors so that they gain confidence in their own actions. (NCTM, 1989, p. 12)

Constructivism, the foundation of the reform movement, is an "active process of mental construction and sense making" (Shepard, 2000, p. 99) in which learners engage in inquiry and discovery, construct their own mathematical knowledge, and develop mathematical creativity and independence (Lambdin, 1998; NCTM, 2000). This view calls on educators to replace a curriculum that treats "mathematics as a rigid system of externally dictated rules governed by

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standards of accuracy, speed, and memory" (National Research Council [NRC], 1989, p. 44) with a curriculum in which students "construct their own knowledge through the investigation of realistic mathematical problems" (Lambdin, 1998, p. 98).

Reform-oriented, or standards-based, teaching practices include posing worthwhile mathematical tasks, facilitating students' task completion through questioning, and encouraging students to make conjectures about and connections between mathematical concepts (McGee, Polly, & Wang, 2013; NCTM, 2000; NCTM, 2014). These practices require students to "actively incorporate information into an existing set of understandings" (Stocks & Schofield, 1997, p. 284) and engage with the teacher as a co-constructor of knowledge (Peterson, Fennema, Carpenter, & Loef, 1989). Reforms also emphasize the importance of teachers creating a context for learning that fosters student understanding through teacher and student discourse (Peressini et al., 2004).

Teacher Beliefs and Practices

The beliefs that teachers hold about the teaching and learning of mathematics influence the instructional strategies they select and enact (Ross, Hogaboam-Gray, & McDougall, 2002; Polly, McGee, Wang, Lamber, Pugalee, & Johnson, 2013). Beliefs that reflect the view of teaching and learning described in The National Council of Teachers of Mathematics' (NCTM) *Principles and Standards for School Mathematics* (2000) are considered by many teacher educators and researchers to be the most supportive of reform-oriented

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instructional practices (Francis, 2015). These reform-oriented teachers believe that students construct their own knowledge and that instruction should focus on understanding and problem solving, be driven by the development of students' ideas, and provide students with opportunities to socially construct knowledge through a community of learners (Peterson et al., 1989). Additionally, teachers with this view believe that all students can and should learn mathematics with understanding.

Understanding teachers' beliefs is a major step toward understanding teachers' instructional practices (Wilkins, 2008; Thompson, 1992; Pajares, 1992; Nespor, 1987). Mathematics teachers' beliefs reflect personal theories about the nature of mathematics and mathematics teaching and learning that influence their decision-making and choice of instructional practices (Pajares, 1992). Specifically, "Mathematics teachers' beliefs have an impact on their classroom practice, on the ways they perceive teaching, learning, and assessment, and on the ways they perceive students' potential, abilities, dispositions, and capabilities" (Barkatsas & Malone, 2005, p. 71).

There is a complicated relationship between mathematics teachers' beliefs and instructional practices in which causality is difficult to explain. Some studies have found that beliefs influence instructional decisions while others have found that practice influences beliefs (Buzeika, 1996). "Although the complexity of the relationship between conceptions and practice defies the simplicity of cause and effect, much of the contrast in the teachers' instructional emphasis may be explained by differences in their prevailing views of mathematics" (Thompson,

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1984, p. 119). In fact, beliefs are the best indicators of decisions that individuals will make (Pajares, 1992).

STEAM Instructional Approaches and Reform-oriented Practices

STEAM is an evolving movement in the educational community. This movement was born out of the emphasis in recent years on developing stronger science, technology, engineering, and mathematics (STEM) curriculums and programs to boost innovation and secure the national economy (Johnson, Adams, Estrada, & Freeman, 2015). STEAM reflects a more balanced approach that integrates the arts and humanities into the sciences. Yackman (2007) explains the complex relationships among the elements of STEAM in stating, "We live in a world where you can't understand science without technology, which couches most of if its research and development in engineering, which you can't create without an understanding of the arts and mathematics" (p. 15). He continues, "Education should more naturally reflect the world it teaches about" (Yackman, 2007, p. 15).

STEAM attempts to meet this challenge by adopting a transdisciplinary approach to learning that focuses on problem solving. Transdisciplinary approaches move "beyond the disciplines," using the collective expertise from different disciplines to solve authentic problems (Quigley & Herro, 2016). "The goal of this approach is to prepare students to solve the world's pressing issues through innovation, creativity, critical thinking, effective communication, collaboration, and ultimately new knowledge" (Quigley and Herro, 2016, p. 410). STEAM instructional approaches prioritize problem solving, authentic tasks,

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inquiry, process skills, student choice, and technology integration. The problem-based nature of STEAM instructional approaches provides a context for learning, presents multiple lines of inquiry, and situates the learning in real world situations, which provide a setting for process skills such as creativity and collaboration. Authentic tasks tap students' interests by addressing real world, timely, and local issues. Inquiry rich experiences are driven by students' curiosity, wonder, interest, and passion and require students to find their own pathways through the problem. Additionally, student choice encourages multiple ways to solve a problem and provides opportunities for students to choose the path they take when solving the problem. Finally, technology integration enhances student learning by engaging 21st Century Skills.

Given the mutual goals of STEAM and the reform movement in mathematics education, the recent emphasis on STEAM instructional practices may be one vehicle for achieving the aims of the reform movement in mathematics education.

Statement of the Problem

Many elementary mathematics teachers hold beliefs about the teaching and learning of mathematics and enact practices that are not aligned with the recommendations of reform efforts in the field of mathematics education (Stigler & Hiebert, 2009; Polly et al., 2013). While the standards-based reform movement began in the 1980's, only minimal change has occurred at the classroom level in critical areas that affect children (Herrera & Owens, 2001). For standards-based reform to gain any significant success, many teachers will have to alter the

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deeply held beliefs that they have about mathematics teaching and learning (Ellis & Berry, 2005). Additionally, the influence of a STEAM setting on mathematics teachers' beliefs and practices is not well understood. On the other hand, STEAM and the mathematics reform movement share overlapping and complementary goals—achieving success with one will likely have a positive effect on the other.

Purpose Statement

Given the role that teachers' beliefs about the nature of mathematics and mathematics teaching and learning play in their selection and enactment of instructional practices, it is essential to understand the influence that different school settings may have on developing and changing teachers' beliefs and practices. The STEAM setting is of particular interest because of its emphasis on problem solving and its emerging popularity in the field of education.

Research Questions

Specifically, the research questions are:

- What are the beliefs about the teaching and learning of mathematics held by elementary mathematics teachers situated in a STEAM school?

- How does teaching in a STEAM school influence the enacted practices and beliefs of teachers about teaching and learning mathematics?

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Significance of the Study

In light of the current push for STEAM schools, research on STEAM instructional approaches and their influence on teachers' enacted practices and beliefs regarding the teaching and learning of mathematics is necessary. This study contributes to a better understanding of how being situated in a STEAM school influences teachers' enacted practices and beliefs about teaching and learning mathematics. Additionally, the findings contribute to the growing field of STEAM education by investigating the influence that teaching in a STEAM school has on the enacted practices and beliefs of elementary mathematics teachers about teaching and learning mathematics.

This research may inform mathematics teacher educators and STEAM program and curriculum designers. Mathematics teacher educators and researchers may use the findings of this study to inform their practice and as a springboard for additional research into the influence of STEAM settings on teachers' beliefs and practices. STEAM program and curriculum designers may consider the influence of STEAM instructional practices on teacher beliefs and enacted practices in mathematics and, ultimately, student learning. They may use the findings to inform and refine their programs. Finally, this study situates teacher learning in a STEAM school. Given the infancy of the STEAM movement, this area is virtually untouched in the current literature. This study contributes to filling this gap in research by revealing a better understanding of how teaching in a STEAM setting influences teachers' enacted practices and beliefs about mathematics teaching and learning.

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Limitations

The setting imposes several limitations on this study. Situating the study in a STEAM elementary school limits the generalizability of the results to STEAM settings with kindergarten through fourth grade students. The number of willing participants also limited this study. Only seven out of the twelve mathematics teachers at the school agreed to participate in the study. The teachers who were not willing to participate cited time limitations and over commitment to other teaching activities as their primary reasons for not participating. It is also possible that the researcher's role as the instructional coach at the school may have deterred some teachers from participating. Additionally, when taken individually, components of the methodology are weak (i.e., surveys that rely on self-reported data). I argue, however, that together the elements form a powerful empirical evidence base for investigating how teaching in a STEAM setting influences teachers' enacted practices and beliefs about mathematics teaching and learning.

Delimitations

I selected the school and the context for this study, which constrains the study to one STEAM school. Additionally, I limited the participants to kindergarten through fourth grade mathematics teachers. I also made specific choices about the methods I employed that further constrain the study. Namely, I chose to use an abbreviated version of the scoop notebook. I made this choice because I feared that requiring the full version would impose too many demands on the teachers and would influence their decision to participate.

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My selection of this particular school poses further constraints because of my role as the instructional coach. As an instructional coach, I am responsible for taking part in professional learning communities, reviewing and providing feedback on lesson plans, facilitating professional development, modeling and observing lessons, and conducting "coaching conversations" with teachers. I also serve on the leadership team and maintain a close relationship with the administrators. While I do not hold an evaluative role, it is possible that teachers view me, to some extent, as an evaluator.

Terms and Definitions

- STEAM is an evolving movement in the educational community. This movement was born out of the emphasis in recent years on developing stronger science, technology, engineering, and mathematics (STEM) curriculums and programs to boost innovation and secure the national economy (Johnson et al., 2015). STEAM reflects a more balanced approach that integrates the arts and humanities into the sciences.

- STEAM instructional approaches prioritize problem solving, authentic tasks, inquiry, process skills, student choice, and technology integration.

- STEAM schools engage students in solving real world problems through a transdisciplinary approach to learning focused on Science, Technology, Engineering, Arts, and Mathematics.

- Transdisciplinary approaches move "beyond the disciplines," using the collective expertise from different disciplines to solve authentic problems (Quigley & Herro, 2016).

- Constructivism is an "active process of mental construction and sense making" (Shepard, 2000, p. 99).

- The reform movement in mathematics education advocates student-centered instructional practices that prioritize inquiry, problem solving, understanding, and discourse.

- Beliefs are "psychologically held understandings, premises, or propositions about the world that are thought to be true" (Philipp, 2007, p. 259).

- Belief systems serve as "a metaphor for describing the manner in which one's beliefs are organized in a cluster, generally around a particular idea or object" (Philipp, 2007, p. 259).

- Affective domain refers to constructs that go beyond the cognitive domain. Beliefs, attitudes, and emotions are considered subsets of affect (McLeod, 1992).

- Attitudes refer to "affective responses that involve positive or negative feelings of moderate intensity" (McLeod, 1992, p. 581).

- Teaching efficacy refers to a teacher's belief in his or her teaching effectiveness.

- Teaching outcome expectancy refers to a teacher's belief that teaching can result in positive outcomes regardless of the external factors.

- Teachers' mathematical beliefs consist of the belief systems held by teachers about the teaching and learning of mathematics (Handal, 2003).

- Constructivist-oriented beliefs maintain that children construct their own knowledge and that instruction should focus on understanding and problem solving, be driven by the development of students' ideas, and provide students with opportunities to socially construct knowledge through a community of learners (Peterson et al., 1989).
- Transmission-oriented teachers' beliefs hold teaching as a process of transmitting knowledge and dispensing information in which students are on the receiving end of the knowledge.

Organization of the Study

I organized this study in five chapters. In Chapter 1, I situate the study broadly in mathematics education, present the problem and purpose statement, research questions, and significance. I also discuss the limitations and delimitations that are present in the study and define relevant terms. In Chapter 2, I provide a discussion of the conceptual framework that was employed, provide an overview of the history of the reform movement in mathematics education, present an extensive review of the relevant literature addressing topic such as teachers' mathematical beliefs, mathematics education reform efforts, and the influence of teachers' beliefs about the nature of mathematics and mathematics teaching and learning on enacted practices and the success or failure of educational reform. In Chapter 3, I describe the methodology in detail. Specifically, I provide a description of the site and sample selection, procedures, measurement instruments, and data analysis. In Chapter 4, I present a detailed account of the findings. Finally, in

Chapter 5, I discuss the implications and significance of the study and provide suggestions for future research endeavors in the field.

CHAPTER 2
LITERATURE REVIEW

The purpose of this chapter is to illustrate, through the literature, the dynamic relationships between mathematics teachers' beliefs about the nature of mathematics and mathematics teaching and learning, reform efforts in mathematics education, and mathematics teachers' instructional practices. This review is meant to provide readers with a roadmap of existing literature in the field related to the research questions outlined in this study.

According to Boote and Beile (2005), a quality literature review reflects "a thorough, critical examination of the state of the field that sets the stage for the authors' substantive research projects" (p. 9). With that goal in mind, I conducted a comprehensive and systematic literature review in the spring and fall of 2016, bearing directly on mathematics' teachers beliefs about the nature of mathematics and mathematics teaching and learning, the barriers these beliefs may pose to reform efforts in mathematics education, mathematics' teachers enacted practices, and the requirements for achieving success with reform efforts. I conducted a keyword search in Google Scholar. No publication date limits were set. The search used combinations of keywords such as "mathematics teachers' beliefs," "mathematics education reform," "changing beliefs," and "standards-based reform." The literature was sifted through and

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narrowed to notable research journals, publications, and books. I also used the citations in many of these works to lead to related works. Through this iterative process, I narrowed the results to what I deem a comprehensive inventory of the literature relating to this study. The research is organized into seven categories: the conceptual framework, the history of mathematics reform, the misalignment between reform efforts and teachers' beliefs, beliefs/belief systems, the affective domain, the influence of teachers' beliefs on instructional practices, and accomplishing the goals of reform.

Conceptual Framework

In this section, I will describe the conceptual framework for this study, including the components of the framework and how the components relate to one another and the study as a whole. This study is framed by the theory of situated learning (Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991). The situated learning theory adopts the assumption that experiences of learning cannot be separated from the situated elements in which they occur (Lave, 1988), commonly referred to as *communities of practice*. Communities of practice are comprised of the community's unique ways of thinking, being, and doing (Wenger & Snyder, 2000). My approach to this research is based on the belief that teacher learning is situated in particular contexts. Knowledge constructions, therefore, are studied as cognitive exercises that occurred within an inseparable social situation (Wenger & Snyder, 2000).

Maxwell (2005) describes the conceptual framework as a way to communicate the researcher's point of view, identify the setting and subjects

being studied, and summarize the literature and existing research that frames the study. The conceptual framework provides the reader with a context for understanding the issues and people being studied. In short, the conceptual framework is a way to explain the main things to be studied: "the key factors, concepts, or variables [of the study], and the presumed relationships among them" (Miles and Hubberman, 1994, p. 18). It lays out the theory that supports and informs the research (Maxwell, 2005). The situated learning theory was chosen to frame this doctoral study. The situated learning theory will serve to help me understand changes in teachers' beliefs and instructional practices that occurred while teaching mathematics in a STEAM context.

Situated learning theory: Historical origins.

Situated learning theory, also known as situated cognition (Brown et al., 1989; Lave & Wenger, 1991), has its roots in social constructivism. Situated learning emerged from various theories, such as activity theory, the sociocultural theory of Vygotsky, Dewey's pragmatism, and ecological psychology, and has been influenced by different perspectives, such as psychology, sociology, and anthropology (Chaiklin & Lave, 1993; Kirshner & Whitson, 1997; Wilson & Myers, 2000). These theories have common core assumptions about human learning and cognition. They assume that knowledge is situated in context; activities, concepts, and culture are integrally connected within the broader system; and learning involves activities, concepts, and culture (Brown et al., 1989; Lave & Wenger, 1991). In 1989, Brown et al. developed situated cognition, which highlighted the importance of teaching concepts in contexts that can be applied

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in the real world. In 1991, social cognitive anthropologists, Jean Lave and Etienne Wenger, discussed the notions around collaborative learning and communities of practice.   The work of both groups of researchers has informed one another and continued to evolve to refine the theory. From a situative perspective, the process of learning occurs as the meaning is created in social and cultural contexts through the authentic activities of daily living. This notion suggests that learning takes place through social contexts and relationships and by connecting prior knowledge to new contexts. In short, the situated learning theory views learning and knowledge as embedded in social contexts and experiences, and promoted through interactive, reflective exchanges among participants in the community of practice. There are three conceptual themes that are central to the situative perspective--that learning is situated in particular physical and social contexts, that learning is social in nature, and that learning is distributed across individuals, people, and tools (Putnam & Borko, 2000).

Learning as situated.

Situated theorists challenge the assumption of early cognitive theorists who treat knowing and learning as the acquisition of knowledge that occurs inside the mind of an individual (Brown et al., 1989; Lave & Wagner, 1991). "They posit, instead, that the physical and social contexts in which an activity takes place are an integral part of the activity, and that the activity is an integral part of the learning that takes place within it" (Putnam & Borko, 2000, p. 4). Additionally, where the traditional cognitive perspective treats the individual as the basic unit of analysis, situative theorists focus on individuals as

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participants who interact with each other as well as materials and representational systems (Greeno, 1997).

The social context of learning and social interaction among and between learners are important aspects of the situated learning theory. Lave (1988) explains that situated learning occurs as the function of an activity and the context and culture in which that activity is situated. He noted the importance of the social construct of learning and how people in groups acquire knowledge. Situated learning theorist view learning not as an isolated process, but the construction of meaning as tied to specific contexts and purposes. Individuals and the world in which they live, where events and activities happen, cannot be separated. Therefore, learning is social and comes from the experience of participating in daily life. Lave (1988) argued that knowledge is socially defined, interpreted, and supported. Brown et al. (1989) agree that knowledge is a product of a meaning-making process and cannot be separated from its context. They suggest that, while it is important to recognize that learners enter situations with knowledge, experiences, and their personal identities, activity and situations are an integral component of cognition.

This view conceptualizes the learning process as being inherently related to the social and cultural contexts in which it occurs. Situated learning theorists challenge the assumption that social and cognitive process can be clearly partitioned off from one another. Instead, they view learning as profoundly influenced by the context in which it occurs. From this perspective, the physical and social contexts in which an activity takes place are an integral part of the

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activity and the activity is an integral part of the learning that takes place within the context. "How a person learns a particular set of knowledge and skills, and the situation in which a person learns, become a fundamental part of what is learned" (Putnam & Borko, 2000, p. 4). Lave and Wenger (1991) believe that learning is an essential and inseparable aspect of social practice in the lived-in world. Their perspective is that "there is no activity that is not situated" (p. 33).

Learning as social: Communities of practice.

Learning and the construction of knowledge is a dynamic and interactive process (Lave, 1988; Vygotsky, 1978). This interactive process illustrates another aspect of the situated learning theory in which learning evolves as a result of membership in a group (Lave & Wenger, 1991). This aspect of situated learning focuses on how individuals, activities, and the world constitute each other within groups labeled as *communities of practice* (Lave & Wenger, 1991). The concept of communities of practice is located within situated perspectives on learning which regard learning and the construction of knowledge as occurring within the practices of communities in social and cultural contexts (Brown et al., 1989; Lave & Wenger, 1991; Wenger, 1998). "The term 'practice' is defined as the routine, everyday activities of a group of people who share a common interpretive community" (Henning, 2004, p. 143). From this point of view, learning is not only making meaning through practice in an activity or using tools or signs to understand activities but, more importantly, learning is co-constructed by members in the community. "The role of others in the learning process goes beyond providing stimulation and encouragement for individual construction of

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knowledge" (Putnam & Borko, 2000, p. 5). Knowledge is, therefore, not an object and memory is not a location. Knowledge is, instead, located in the actions of people and groups of people. These interactions between members of a group determine both what is learned and how the learning takes place. Communities of practice have "a particular set of artifacts, forms of talk, cultural history, and social relations that shape, in fundamental and generative ways, the conduct of learning" (Henning, 2004, p. 143). These communities "provide the cognitive tools--ideas, theories, and concepts--that individuals appropriate as their own through their personal efforts to make sense of experiences" (Putnam & Borko, 2000, p. 5). In other words, learning is a process of enculturation in which individuals observe and practice behaviors of the members of a culture and adopt relevant jargon, imitate behaviors, and eventually behave in agreement with the norms of that culture. It is important to note that cultural models are not held by individuals, but live in the practices of a community and how individuals interact with one another. Consequently, as situations shape individual cognition, individual thinking and action, in turn, shape the situation through the ideas and ways of thinking that individuals bring to the situation. Brown et al. (1989) agree that the conceptual tools of a community of practice "reflect the cumulative wisdom of the culture in which they are used and the insights and experience of individuals" (p. 33). From this perspective, learning is viewed "as the ongoing and evolving creation of identity and the production and reproduction of social practices both in school and out that permit social groups, and the individuals in these groups to maintain commensal relations that promote the life of the group"

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(Henning, 2004, p. 143).

Lave and Wenger (1991) identified four intertwined and interdependent components of communities of practice. These components are community, identity, practice, and meaning. A true community of practice does not exist without each of these components. Chaiklin &Lave (1993) and Wenger (1998) view learning is a social practice that occurs as increased participation in communities of practice. Learning, therefore, is defined as becoming a better participant in practice (Brodie, 2005). According to Borko (2004), "Situative theorists conceptualize learning as changes in participation in socially organized activities, and individuals' use of knowledge as an aspect of their participation in social practices" (p.4). Knowledge is co-constructed and negotiated in the community of practice, which implies that knowledge is a property of the community (Wenger, 1998). Participation in these communities refers to the "process of being active participants in the practices of social communities and constructing identities in relation to these communities" (Wenger, 1998, p. 4). Such participation shapes what people do, who they are, and how they interpret what they do (Wenger, 1998).

Learning as distributed.

Finally, the situative perspective views learning as distributed or "stretched over" (Lave, 1988) the individual, other people, and various artifacts including physical and symbolic tools. This aspect of the situative perspective suggests "that human intelligence is distributed beyond the human organism by involving

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other people, using symbolic media, and exploiting the environment and artifacts"
(Henning, 2004, p. 147).

Situated learning theory as a framework for this study.

Learning is a highly complex process comprised of a variety of factors
including motivation, attitude, and affect (Sarason, 2004). One of the greatest
challenges facing teacher educators and researchers is understanding how to
create learning experiences powerful enough to transform teachers' classroom
practice. "If we wish to understand and influence people's teaching, we must go
beneath the surface to consider the intentions and beliefs related to teaching and
learning which inform their assumptions" (Pratt, 1998, p. 11). Studies of learning
demonstrate that the content of what is learned is often tied to the context in
which it is learned (Henning, 2004). These findings have paved the way for a
view of learning that is situated in communities of practice as opposed to the
acquisition of knowledge which can be applied in a variety of situations (Brown et
al., 1989; Lave, 1988; Resnick, 1987). A situated perspective (Greeno, 1997;
Greeno, Collins, & Resnick, 1996; Lave & Wenger, 1991) enables teacher
educators to think about teacher learning more productively (Putnam & Borko,
2000). Putnam and Borko (2000) explain, "The language and conceptual tools of
social, situated, and distributed cognition provide powerful lenses for examining
teaching, teacher learning, and the practices of teacher education in new ways"
(p. 12). The situated perspective assumes that knowing and learning are integral
and inseparable aspects of all human activity. Learning, therefore, is situation
specific and depends on the context in which it occurs. How and where a person

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learns a particular set of knowledge and skills play a fundamental role in what is learned (Putnam & Borko, 2000). Additionally, social influence has a profound impact on what is learned. The situated perspective focuses on communities of practice which include individuals as participants who interact with each other as well as tools and representational systems (Greeno, 1997). The interactions within these communities of practice are major determinants of what is learned and how it is learned.

When applied to teacher learning, the situated perspective suggests that teacher learning should be grounded in some aspect of teacher practice. Much of what teachers learn is situated within the context of classrooms and teaching (Carter, 1990; Carter & Doyle, 1989). Communities of practice are formed within these contexts and become the locus for teacher learning and play central roles in shaping what teachers learn and how they go about doing their work (Putnam & Borko, 2000). Putnam and Borko (2000) warn that the patterns of thought and action within the context of the classroom may be resistant to reflection or change. "A combination of approaches, situated in a variety of contexts, hold the best promise for fostering powerful, multidimensional changes in teachers' thinking and practice" (Putnam & Borko, 2000, p. 7).

I chose to frame this doctoral study within the situated learning theory in an effort to "critically examine learning, teaching, and instructional design from a practice-based approach" (Henning, 2004, p. 143). I will take the stance that teachers' learning is situated in their community of practice and that the content of what is learned is tied to the context in which it is learned. In this situation, the

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context is a kindergarten through fourth grade elementary school with an emphasis on STEAM instructional practices. I will investigate how this setting influences teacher beliefs and practices about teaching and learning mathematics—What is learned and how is that learning tied to the context of a STEAM educational setting? The situated learning theoretical perspective helped frame the research questions by investigating teachers' enacted practices and beliefs about mathematics teaching and learning when situated in a STEAM school. The study will take place in this community of practice which will give access to the individuals within the community as well as the tools and representational systems and how they all interact.

Historical Context: Mathematics Education Reform

To understand the current reform movement, it is important first to explore the history of mathematics education reform. The teaching and learning of mathematics in the early twentieth century was profoundly influenced by Thorndike's Stimulus-Response Bond Theory (Thorndike, 1923). Thorndike theorized that mathematics is best learned through drill and practice and viewed mathematics as a "hierarchy of mental habits or connections" (Thorndike, 1923, p. 52). His use of "scientific" evidence to support his claim that mathematics is best learned through drill and practice led a large portion of the mathematics community to embrace this view (Ellis & Berry, 2005).

The Progressive Movement of the 1920's was a reaction against the highly structured, rote instructional practices that were born out of Thorndike's theories. Influenced by John Dewey (1899), early progressive educators believed that

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learning occurs best when it is connected to students' experiences and interests. The beginning phase of the progressive movement had little impact on schooling practices because it was perceived by many educators to be radical (Ellis & Berry, 2005). The social efficiency movement, an offshoot of the early progressive movement, had a more profound impact on mathematics education. The social efficiency movement questioned the importance of secondary mathematics for all students. The study of advanced mathematics, proponents argued, was best suited for those who had a future need for the subject. By the 1940's, the combined effects of Thorndike's structured "scientific" teaching methods and the social efficacy movement's sorting of students based on future needs resulted in tracking in mathematics education where most students were placed in vocational, consumer, and industrial mathematics courses (Ellis & Berry, 2005).

The "new math movement" of the 1960's and 1970's was born out of a sense of national crisis that emerged from the launch of *Sputnik*. These concerns and the discontent with the lack of rigor in high school mathematics preparation led to the inclusion of K-12 mathematics education as a funding area and set the stage for the "new math" (Herrera & Owens, 2001). There was a national concern that the United States needed more technical and mathematical skills to push forward in the developing technological age. This national concern led the National Council for Teacher of Mathematics (NCTM), the world's largest mathematics education organization, to appoint the Commission on Postwar Plans. The goal of the Commission was to make recommendations about

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mathematics curriculum to "establish the United States as a world leader and to continue the technological development that had begun during the crisis of war" (Herrera & Owens, 2001, p. 84). The Soviet Union's launch of the first satellite, *Sputnik*, into space increased the sense of urgency and catapulted the "new math movement" that had already begun. A more rigorous mathematics curriculum was seen as a necessity in maintaining national security. The "new math movement" emphasized deductive reasoning, set theory, rigorous proof, and abstraction. Many opponents of the "new math movement" argued that the concepts and mathematical structures were overly rigorous and complex (Dickey, 2010). Additionally, the implementation of New Math curriculum was uneven and not accompanied by the professional development and materials necessary to teach well. Eventually, there was a widespread sentiment that the "new math" had failed and a return to the basics was needed (Herrera & Owens, 2001).

The backlash over the "new math movement" led to the back-to-the-basics era of the 1970's. The back-to-the-basics era emphasized computation and algebraic manipulation and gave little priority to problem solving.

Mathematics teaching during the back-to-the-basics era was characterized by the National Science Foundation case studies:

In all math classes that I visited, the sequence of activities was the same. First, answers were given for the previous day's assignment. The more difficult problems were worked by the teacher or the students at the chalkboard. A brief explanation, sometimes none at all, was given of the

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new material, and the problems assigned for the next day. The remainder of the class was devoted to working on homework while the teacher moved around the room answering questions. The most noticeable thing about math classes was the repetition of this routine. (Welch, 1978, quoted in NCTM, 1991, p. 1)

Once again, mathematics education in the back-to-the-basics era was met with a sense of national crisis spurred by a perceived falling behind in global technological and economic standings (Herrera & Owens, 2001).

The publication of *A Nation at Risk* (1983) awakened the general public to a sense of crisis (Herrera & Owens, 2001). The report's strong rhetoric sparked a sense of urgency: "If an unfriendly foreign power had attempted to impose on America the mediocre educational performance that exists today, we might well have viewed it as an act of war" (NCEE, 1983, p. 5). As a leader in mathematics education, NCTM was once again prompted to form a committee to develop recommendations for school mathematics. Consequently, NCTM published *An Agenda for Action: Recommendations for School Mathematics of the 1980's*. The booklet explained eight recommendations for school mathematics related to teaching, learning, technology, and professionalism and proposed making problem solving the focus of school mathematics (Wilson, 2003; Dickey, 2010). NCTM responded to the call to action brought forth by the publication of *A Nation at Risk* (1983) by assuming an advocacy role and publishing the *Curriculum and Evaluation Standards for School Mathematics* in 1989. The release of this publication ignited the "standards movement" across all school subjects. The

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release of the initial standards was followed by the publication of the *Curriculum and Evaluation Standards for School Mathematics* (1991) and the *Assessment Standards for School Mathematics* (1995). These standards projects influenced national policy and served as a guide in nearly every state to adopt policies and curriculum for mathematics education (McLeod, 2003; Dickey, 2010). In 2000, NCTM released *Principles and Standards for School Mathematics* (2000), a refinement of the original standards. The standards continue to challenge conventional instructional practices by advocating changes in content and pedagogy. The central focus of the content in the standards is on the conceptual versus the merely procedural. Additionally, the pedagogy described in the standards is based in constructivism which views the learner as an active participant in the construction of knowledge and shifts the role of the teacher from the giver of knowledge to an orchestrator of classroom discourse and facilitator of learning experiences (Herrera & Owens, 2001). Most recently, NCTM published the *Principles to Actions: Ensuring Mathematical Successes for All* (2014). This publication builds on NCTM's preceding work with standards by providing five essential elements of school mathematics programs and eight research-based mathematics teaching practices (NCTM, 2014).

The publication of the *Curriculum and Evaluation Standards for School Mathematics* (1989) sparked controversy between the traditionalists and reformers that has been coined the "math wars." The reformers are proponents of NCTM's recommendations for teaching and learning mathematics. The traditionalists, on the other hand, criticize standards-based reform by pointing to

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an erosion of computational skills and procedural fluency (Gates, 2003; Dickey, 2010).

The following quote from one of the leading opponents of standards-based reform, *Mathematically Correct*, conveys the counter view to standards-based reform:

Across the country, the way mathematics is taught in the classroom and in textbooks has been changing notably. Classrooms are often organized in small groups where students ask each other questions and the teacher is discouraged from providing information…The use of blocks and other "manipulative" objects has extended well beyond kindergarten and can now be found in many algebra classes. Meanwhile, the students practice their fundamentals less and less…Calculator use is growing and taking away expectations for student learning. Textbooks, if the students have them at all, are full of color pictures and stories, but not full of mathematics. The books often don't even give explicit explanations or procedures. That would be "telling" and the new idea is for students to discover all of the mathematics for themselves. Many of these programs don't even teach the standard algorithms for the operations of arithmetic. Long division is a devil that has to be beaten into extinction—and if they manage that, multiplication will be next. ("What Has Happened," 2000)

In recent years the "math wars" have continued to rage with the 2010 release of the *Common Core State Standard for Mathematics* (CCSSM). While the CCSSM

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offer a balance of procedural fluency and conceptual understanding, their focus on problem solving and understanding have served to maintain the "math wars."

Misalignment between Reform Efforts and Teachers' Beliefs

While the standards-based reform movement began in the 1980's, only minimal change has occurred at the classroom level in critical areas that affect children (Herrera & Owens, 2001; Stigler & Hiebert, 2009).

Philipp (2007) explains:

One might conclude from the abundance of studies on reform that schools were engaged in important and fundamental change. However, a peek into randomly selected American classrooms has led to the conclusion that the reform movement in the United States has not led to widespread change in mathematics instruction. (p. 263)

The primary obstacle to reform implementation is teachers' beliefs about the nature of mathematics and mathematics teaching and learning that are incompatible with those beliefs underlying reform efforts (Ross, Hogaboam-Gray, & McDougall, 2002; Polly et al., 2013; Stigler & Hiebert, 2009).

Stigler and Hiebert (2009) explain:

Teaching is not a simple skill, but rather a complex cultural activity that is highly determined by beliefs and habits that work partly outside the realm of consciousness. (p. 103)

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These prevailing beliefs serve as impediments to the current reform efforts in mathematics education (Goldin, Rosken, & Torner, 2009) and have been cited as the main reason for the failure of reform efforts (Schoenfeld, 1985). Battista (1994) argues that "this incompatibility blocks reform and prolongs the use of a mathematics curriculum that is seriously damaging the mathematical health of our children" (Battista, 1994, p. 462). In fact, some researchers argue that because teachers often misinterpret reform recommendations, reform efforts may actually worsen the quality of instruction (Stigler & Hiebert, 2009).

Stigler and Hiebert (2009) explain:

Reform documents that focus teachers' attention on features of "good teaching" in the absence of supporting contexts might actually divert attention away from the more important goals of student learning. (p. 107)

Teachers undoubtedly play a fundamental role in reform efforts, and for standards-based reform to gain any significant success, many teachers will have to alter the deeply held beliefs that they hold about mathematics teaching and learning (Ellis & Berry, 2005). Additionally, Stigler and Hiebert (2009) argue, because teaching is a cultural activity that is influenced by beliefs, "the writing of reform documents is an unrealistic way to improve education" (p. 108).

Standards-Based Reform

The reform movement in mathematics education characterizes mathematics learning as an active process in which students construct their own mathematical knowledge from personal experiences as they interact with peers,

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teachers, and other adults as co-constructors of knowledge (NRC, 2012;
Donovan & Bransford, 2005; Lester, 2007).

Supporters of the reform movement envision classrooms in which
students:

Have numerous and various interrelated experiences which allow them to
solve complex problems; to read, write, and discuss mathematics; to
conjecture, test, and build arguments about a conjecture's validity; to
value the mathematical enterprise, the mathematical habits of mind, and
the role of mathematics in human affairs; and to be encouraged to
explore, guess, and even make errors so that they gain confidence in their
own actions. (NCTM, 1989, p. 12)

Constructivism, the foundation of the reform movement, is an "active process of
mental construction and sense making" (Shepard, 2000, p. 99) in which learners
engage in inquiry and discovery, construct their own mathematical knowledge,
and develop mathematical creativity and independence (Lambdin, 1998; NCTM,
2000). The reform movement calls on educators to replace a curriculum that
treats "mathematics as a rigid system of externally dictated rules governed by
standards of accuracy, speed, and memory" (NRC, 1989, p. 44) with a curriculum
in which students "construct their own knowledge through the investigation of
realistic mathematical problems" (Lambdin, 1998, p. 98).

Reform-oriented, or standards-based, teaching practices engage students
in solving and discussing tasks that promote reasoning and problem solving

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(McGee et al., 2013; NCTM, 2000; NCTM, 2014). These practices require students to "actively incorporate information into an existing set of understandings" (Stocks & Schofield, 1997, p. 284) and engage with the teacher as a co-constructor of knowledge (Peterson et al., 1989). Reforms also emphasize the importance of teachers creating a context for learning that fosters student understanding through teacher and student discourse (Peressini et al., 2004).

NCTM (2000) described the role of problem solving in "reformed" classrooms:

Students require frequent opportunities to formulate, grapple with, and solve complex problems that involve a significant amount of effort. They are to be encouraged to reflect on their thinking during the problem solving process so that they can apply and adapt the strategies they develop to other problems and in other contexts. By solving mathematical problems, students acquire ways of thinking, habits of persistence and curiosity, and confidence in unfamiliar situations that serve them well outside the mathematics classroom. (p. 53)

For this study, this description will serve as the operational definition for problem solving.

Eight Mathematics Teaching Practices.

NCTM's *Principles to Actions: Ensuring Mathematical Success for* All (2014) presents eight research-based teaching practices that are informed by

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research and support the mathematics learning for all students. The "Eight Mathematics Teaching Practices provide a framework for strengthening the teaching and learning of mathematics" (NCTM, 2014, p. 9). These practices "represent a core set of high-leverage practices and essential teaching skills necessary to promote deep learning of mathematics" (NCTM, 2014, p. 9). The *Eight Mathematics Teaching Practices* include:

1. Establish mathematics goals to focus learning.
2. Implement tasks that promote reasoning and problem solving.
3. Use and connect mathematical representations.
4. Facilitate meaningful mathematical discourse.
5. Post purposeful questions.
6. Build procedural fluency from conceptual understanding.
7. Support productive struggle in learning mathematics.
8. Elicit and use evidence of student thinking.

In the following discussions, I will cite the practices by their corresponding number. For example, I will refer to the practice of *establishing mathematical goals to focus learning* as Practice #1.

Effective mathematics teachers, NCTM (2014) explains, move "towards improved instruction through the lens of these core teaching practices" (p. 57).

NCTM (2014) described this process:

Effective teaching of mathematics begins with teachers clarifying and understanding the mathematics that students need to learn and how it

develops along learning progressions. The establishment of clear goals supports the selection of tasks that support reasoning and problem solving while developing conceptual understanding and procedural fluency. With effective teaching, the classroom is rich in mathematical discourse among students in using and making connections among mathematical representations as they compare and analyze varied solution strategies. The teacher carefully facilitates this discourse with purposeful questioning. Teachers acknowledge the value of productive struggle in learning mathematics, and they support students in developing a disposition to persevere in solving problems. They guide their teaching and learning interactions by evidence of student thinking so that they can access and advance student reasoning and sense making about important mathematical ideas and relationships. (p. 57)

For the purposes of this study, I will use the Eight Mathematics Teaching Practices as a framework for "reformed" mathematics teaching.

STEAM instructional approaches and reform-oriented practices.

STEAM (Science, Technology, Engineering, Arts, and Mathematics) is an evolving movement in the educational community. This movement was born out of the emphasis in recent years on developing stronger science, technology, engineering, and mathematics (STEM) curriculums and programs to boost innovation and secure the national economy (Johnson et al., 2015). STEAM reflects a more balanced approach that integrates the arts and humanities into

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the sciences. Yackman (2007) explains the complex relationships among the elements of STEAM in stating, "We live in a world where you can't understand science without technology, which couches most of if its research and development in engineering, which you can't create without an understanding of the arts and mathematics" (p. 15). He continues, "Education should more naturally reflect the world it teaches about" (Yackman, 2007, p. 15).

STEAM attempts to meet this challenge by adopting a transdisciplinary approach to learning that focuses on problem solving. Transdisciplinary approaches move "beyond the disciplines," using the collective expertise from different disciplines to solve authentic problems (Quigley & Herro, 2016). "The goal of this approach is to prepare students to solve the world's pressing issues through innovation, creativity, critical thinking, effective communication, collaboration, and ultimately new knowledge" (Quigley and Herro, 2016, p. 410). STEAM instructional approaches prioritize problem solving, authentic tasks, inquiry, process skills, student choice, and technology integration. The problem-based nature of STEAM instructional approaches provides a context for learning, presents multiple lines of inquiry, and situates the learning in real world situations which provide a setting for process skills such as creativity and collaboration. Authentic tasks tap students' interests by addressing real world, timely, and local issues. Inquiry rich experiences are driven by students' curiosity, wonder, interest, and passion and require students to find their pathways through the problem. Additionally, student choice encourages multiple ways to solve a problem and provides opportunities for students to choose the path they take

when solving the problem. Finally, technology integration enhances student learning by engaging 21st Century Skills. "In regard to STEAM teaching, this points to the necessity of technology and twenty-first century skills as the foundation for teachers and their students to practice, collaborate, and apply requisite skills in STEAM units" (Quigley & Herro, 2016, p. 413). Given the mutual goals of STEAM education and the reform movement in mathematics education, the recent emphasis on STEAM instructional practices may be one vehicle for achieving the goals of the reform movement in mathematics education.

Beliefs/Belief Systems

Given that beliefs "act as cognitive and affective filters through which new knowledge and experience is interpreted," (Handal & Herrington, 2003, p. 59) teachers' beliefs are a significant factor in developing an understanding of mathematics teaching and learning (Green, 1971). While many researchers have studied beliefs, there is no explicit agreement about the universal definition of beliefs (Philipp, 2007). Thompson (1992) described beliefs as a subset of conceptions. While she seemed to use the two terms interchangeably, she described conceptions "as a more general mental structure encompassing beliefs, meanings, concepts, propositions, rules, mental images, preferences, and the like" (p. 130). Rokeach (1968) described beliefs as having a cognitive component (knowledge), an affective component (arousing emotion) and a behavioral component that is activated when action is required. For this study, I will adopt Philipp's (2007) definition of beliefs as "psychologically held

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understandings, premises, or propositions about the world that are thought to be true" (p. 259).

Belief systems serve as "a metaphor for describing the manner in which one's beliefs are organized in a cluster, generally around a particular idea or object" (Philipp, 2007, p. 259). Green (1971) described three dimensions of belief systems: (1) Some beliefs are *primary* while others are *derivative. Primary* beliefs are developed from direct experience and are more influential than *derivative* beliefs. Furthermore, a belief is never held in total isolation from other beliefs and some serve as the foundation for others; (2) Beliefs can be *central* (strongly held) and *peripheral* (less strongly held and more susceptible to change); (3) Beliefs are held in clusters that are typically isolated from other clusters. These clusters allow individuals to avoid confrontations between belief structures, conceptions, and behaviors. "Primary and central beliefs are difficult to change, particularly when they are clustered and contextualized in relatively independent groups" (Grootenboer, 2008, p. 481). However, Thompson (1992) contends that belief structures are susceptible to change in light of experience and the consideration of how they are held in relation to one another is useful when studying teachers' beliefs.

Goldin et al. (2009) found that there is no universal pattern for beliefs and that they "are highly subjective, and vary according to different bearers" (Goldin et al., 2009, p. 4). Pajares (1992) concurs that beliefs are "deeply personal, rather than universal, and unaffected by persuasion" (p. 309). Pajares (1992) offers fundamental assumptions for researchers to adopt when studying

teachers' educational beliefs. For this study, I will adopt the following assumptions regarding teachers' educational beliefs:

- Beliefs are formed early, tend to self-perpetuate and persevere against contradictions that are presented by reason, time, schooling, or experience.
- Beliefs are influenced by cultural factors and develop over time.
- Beliefs help individuals understand the world and themselves.
- Beliefs act as a filter that affect how one views the world.
- Beliefs are prioritized according to their connections or relationships to other beliefs.
- The earlier a belief is formed, the more difficult it is to change.
- Beliefs strongly influence behavior.
- Beliefs must be inferred.
- Beliefs are not all or nothing entities—they can be held with varying degrees of intensity.

Affective Domain

"Beliefs are embedded in complex affective as well as cognitive structures" (Goldin, Rosken, & Torner, 2009, p. 13) and may be seen as the intersection of the cognitive and affective domains. In fact, Goldin et al., (2009) argue, "Beliefs are interwoven with affect" (p. 4). Affective domain refers to constructs that go beyond the cognitive domain. Beliefs, attitudes, and emotions are considered subsets of affect (McLeod, 1992).

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McLeod (1992) differentiates between these subsets of affect in stating:

> Beliefs are largely cognitive in nature, and are developed over a relatively
> long period of time. Emotions, on the other hand, may involve little
> cognitive appraisal and may appear and disappear rather
> quickly…Therefore we can think of beliefs, attitudes, and emotions as
> representing increasing levels of affective involvement, decreasing levels
> of cognitive involvement, increasing levels of intensity of response, and
> decreasing levels of response stability. (p. 579)

These affective structures are regarded as mutually interacting and may be
simultaneously active at any given time (Goldin et al., 2009; Grootenboer, 2003;
Leder & Grootenboer, 2005; McLeod, 1992). Emotions are less cognitive, felt
more intensely, and more susceptible to change than beliefs or attitudes
(McLeod, 1992). Attitudes refer to "affective responses that involve positive or
negative feelings of moderate intensity" (McLeod, 1992, p. 581). Attitudes are
more cognitive in nature and felt less intensely than emotions. It is important to
note that "repeated emotional reaction to an experience related to mathematics
can result in automatizing that emotion into an attitude toward that experience"
(Philipp, 2007, p. 261). Finally, beliefs are more cognitive in nature than attitudes
and emotions, more stable, and experienced with a lower level of intensity
(McLeod, 1992). Philipp (2007) describes beliefs as "lenses through which one
looks when interpreting the world" (p. 258) and affect as the disposition one takes
toward an aspect of his or her world.

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To fully understand the role played by beliefs and why some beliefs are so centrally and tenaciously held, the affective structures that support them must be considered. It is essential to not only understand *what* beliefs are held but also *how* those beliefs are held as well as the emotional and attitudinal needs that they serve (Goldin et al., 2009). Beliefs may meet emotional needs or provide defense from pain. Goldin et al. (2009) provide the example of a student who believes that mathematical ability is fixed. Holding this belief may serve to relieve the student from responsibility. Additionally, "The belief assuages guilt, alleviates the pain associated with failure, and provides a 'good reason' for him to disengage with doing mathematics before emotional feelings of frustration arise" (Goldin et al., 2009, p. 11). It is clear that affect has a significant influence on mathematics learning (McLeod, 1992). Likewise, a teacher may be attracted to the belief that each student has a fixed mathematical ability. Holding such a belief may help relieve the teacher's sense of frustration with those of her students whose learning is slow or diminish her sense of failure for being unable to improve her students' learning. "To acknowledge the possibility of mathematical talent being acquired may not only be contrary to her experience, but may necessitate confronting emotionally painful issues" (Goldin et al., 2009, p. 11).

Beliefs and affect also have a major influence on mathematics teaching. Beliefs have been linked to the self-concept of individuals and efficacy beliefs are a predictor of successful teaching (Goldin et al., 2009). Teacher efficacy is defined as a teacher's "judgment of his or her capabilities to bring about desired

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outcomes of student engagement and learning, even among those students who may be difficult or unmotivated" (Tschannen-Moran & Hoy, 2001, p. 783). Teaching efficacy is two dimensional—made up of personal teaching efficacy (belief in teaching effectiveness) and teaching outcome expectancy (belief that teaching can result in positive outcomes regardless of the external factors) (Enochs, Smith, & Huinker, 2000; Swars, Hart, Smith, Smith, & Tolar, 2007). Teacher efficacy is related to student achievement, student motivation, teacher behavior, teacher effort, teacher persistence, and teacher resilience (Bandura, 1986; Tschannen-Moran &Hoy, 2001).

Teacher efficacy is subject-matter specific (Tschannen-Moran & Hoy, 2001). Mathematics self-efficacy is "a situational or problem-specific assessment of an individual's confidence in his or her ability to successfully perform or accomplish a particular [mathematical] task" (Hackett & Betz, 1989, p. 262). Mathematics teaching efficacy consists of two parallel dimensions—personal mathematics teaching efficacy and mathematics teaching outcome expectancy (Enochs et al., 2000). Unfortunately, elementary mathematics teachers have increased mathematics anxiety, decreased self-concept, and more negative attitudes toward mathematics (Ball, 1990). Teachers with strong beliefs in their capacity to teach mathematics effectively are more likely to possess sophisticated mathematical beliefs (Briley, 2012). In fact, "Mathematics teaching efficacy was found to have a statistically significant positive relationship to the belief about the nature of mathematics, to the belief about doing, validating, and

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learning mathematics, and the belief about the usefulness of mathematics"
(Briley, 2012, p. 8).

Philipp (2007) insists, "Teachers' affect is critically important! If
prospective or practicing teachers are to develop deeper content knowledge and
richer beliefs about mathematics teaching and learning, then positive affect must
be considered" (p. 309). Therefore, it is important for researchers to integrate
affective issues when studying issues related to teaching and learning (McLeod,
1992).

Influence of Teachers' Beliefs on Instructional Practices

Understanding teachers' beliefs is an important step toward understanding
teachers' instructional practices (Wilkins, 2008; Thompson, 1992; Pajares, 1992;
Nespor, 1987). Research has demonstrated that teachers' beliefs about the
nature of mathematics and mathematics teaching and learning play a vital role in
teachers' effectiveness and instructional decision making, including the practices
they enact (Ernest, 1989; Ball, 1991; Richardson, 1996; Fennema & Franke,
1992; Pajares, 1992; Thompson, 1992). Because behavior is mostly instinctive
and intuitive, not reflective and rational (Thompson, 1984), the development of
teachers' teaching practices are significantly affective in nature and directed by
beliefs (Grootenboer, 2008).

Thompson (1984) described how teaching practices might develop:

Teachers develop patterns of behavior that are characteristic of their

instructional practice. In some cases, these patterns may be

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manifestations of consciously held notions, beliefs, and preferences that act as "driving forces" in shaping the teacher's behavior. In other cases, the driving forces may be unconsciously held beliefs or intuitions that may have evolved out of teacher's experience. (p. 105)

In other words, mathematics teachers' beliefs reflect personal theories about the nature of mathematics and mathematics teaching and learning that influence their decision making and choice of instructional practices (Pajares, 1992). Specifically, "Mathematics teachers' beliefs have an impact on their classroom practice, on the ways they perceive teaching, learning, and assessment, and on the ways they perceive students' potential, abilities, dispositions, and capabilities" (Barkatsas & Malone, 2005, p. 71). Raymond (1997) concluded that beliefs teachers hold about mathematics content are more closely related to their instructional practices than the beliefs they hold about mathematics teaching and learning.

In addition to the beliefs that teachers have about the nature of mathematics and mathematics teaching and learning, teachers hold beliefs about teaching that are not specific to teaching mathematics such as beliefs about their students and the social and emotional makeup of their classes. These beliefs play a significant role in teacher decision-making and are likely to take precedence over beliefs that are specific to mathematics teaching and learning (Thompson, 1984).

There is a complicated relationship between mathematics teachers' beliefs and instructional practices in which causality is difficult to explain. Some studies have found that beliefs influence instructional decisions while others have found that practice influences beliefs (Buzeika, 1996). "Although the complexity of the relationship between conceptions and practice defies the simplicity of cause and effect, much of the contrast in the teachers' instructional emphasis may be explained by differences in their prevailing views of mathematics" (Thompson, 1984, p. 119). In fact, beliefs are the best indicators of decisions that individuals will make (Pajares, 1992).

Teacher Beliefs

"All teachers hold beliefs, however defined and labeled, about their work, their students, their subject matter, and their roles and responsibilities, but a variety of conceptions of educational beliefs has appeared in literature" (Pajares, 1992, p. 314). Teachers' mathematical beliefs consist of the belief systems held by teachers about the teaching and learning of mathematics (Handal, 2003). These views represent "implicit assumptions about curriculum, schooling, students, teaching and learning, and knowledge" (Handal & Herrington, 2003, p. 59). Schoenfeld (1985) suggests that mathematics teachers' beliefs can be seen as an individual's perspective on how one engages in mathematical tasks.

Philipp (2007) identified a spectrum of mathematics teachers' beliefs that is consistent with the constructivist/traditional framework of classifying instructional practice. More specifically, Thompson, Thompson, and Boyd (1994)

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describe teachers' orientations towards teaching mathematics by characterizing the nature of mathematical discourse that is exemplified by their enacted practices. They explain that the images that teachers have of the mathematics they teach "manifest themselves in two sharply contrasting orientations towards mathematics teaching" (Thompson, Thompson, & Boyd, 1994, p. 1). "Calculational" oriented teachers focus on the problem to be solved, prioritize the answer, and maintain expectations for students' explanations that are shallow and incomplete (Thompson, Thompson, & Boyd, 1994). Thompson, Thompson, and Boyd (1994) continue, "A teacher with a calculational orientation is one whose actions are driven by a fundamental image of mathematics as the application of calculations and procedures for deriving numerical results" (p. 6).

Thompson, Thompson, and Boyd (1994) illustrate the contrast between the two orientations in explaining:

[Conceptually oriented teachers] focus students' attention away from thoughtless application of procedures and toward a rich conception of situations, ideas and relationships among ideas. These teachers strive for conceptual coherence, both in their pedagogical actions and in students conceptions. As a result, conceptually oriented teachers tend to focus on aspects of situations that, when well understood, give meaning to numerical values and which are suggestive of numerical operations. Conceptually oriented teachers often ask questions that move students to view their arithmetic in a non-calculational context. (p. 7)

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For this study, I will describe and classify teachers' beliefs and practices in terms of *constructivist/reform-oriented* or *transmission/traditional-oriented.* I will ground discussions of reform-oriented practices using the *Eight Mathematics Teaching Practices* discussed earlier in this chapter as a framework (NCTM, 2014). Additionally, I will characterize teachers' practices specific to mathematical discourse (Practice #4) as exemplifying a conceptual (reform) orientation or a computational (traditional) orientation.

Constructivist-oriented beliefs

Teachers who hold constructivist-oriented beliefs maintain that children construct their own knowledge and that instruction should focus on understanding and problem solving, be driven by the development of students' ideas, and provide students with opportunities to socially construct knowledge through a community of learners (Peterson et al., 1989). These teachers treat mathematical tasks as opportunities for sense making, not rule following (Battista, 1994).

Transmission-oriented beliefs.

Transmission-oriented teachers' beliefs hold teaching as a process of transmitting knowledge and dispensing information in which students are on the receiving end of the knowledge. Their teaching approaches are often rote and removed from human experience. Teachers who hold transmission-oriented beliefs are prone to reduce mathematics tasks to step-by-step computational procedures that they can then teach their students to perform, view inability to

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quickly find a solution to a task as failure, focus on correct procedures, coach students to perform the desired procedure and judge them based on their consistency with the desired procedure (Battista, 1994).

The range of teachers' mathematical beliefs is vast (Handal, 2003). In this literature review, I have chosen to highlight teachers' beliefs that are most relevant to the study at hand. I will review teachers' beliefs about the nature of mathematics, students' mathematical thinking, student and teacher roles, what is considered as evidence of mathematical understanding, instructional planning, and curriculum.

Beliefs about the nature of mathematics.

Brown & Cooney (1982) argue, "A teacher's inclination to teach a certain way or to use/not use knowledge learned from a variety of experiences is indeed affected by what he/she believes mathematics is" (p. 16). Individuals with reform-oriented beliefs consider mathematics as a dynamic body of knowledge while teachers with transmission-oriented beliefs view mathematics as static. Karp (1991) found that teachers with negative attitudes toward mathematics enacted instructional practices that are more rule-based and teacher-directed while teachers with more positive attitudes enacted practices that focused on understanding, exploring, and discovering mathematical relationships.

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Beliefs about students' mathematical thinking.

Fennema, Carpenter, Franke, Jacobs, and Empson (1996) investigated mathematics teachers' beliefs and instructional practices as they learned about students' thinking. They categorized teachers' beliefs in four levels:

- Level A: Teachers believe that students learn best by being told how to do mathematics.

- Level B: Teachers are beginning to question the need to show children how to do mathematics and hold conflicting beliefs.

- Level C: Teachers believe that children learn mathematics as they solve many problems and discuss solutions.

- Level D: Teachers accept the idea that children can solve problems without direct instruction and that mathematics instruction should be based on children's abilities

Teachers who studied children's mathematical thinking while learning mathematics developed more sophisticated, reform-oriented, beliefs about mathematics, teaching, and learning than those who did not study children's thinking (Philipp, 2007). Teachers who hold traditional, transmission-oriented beliefs, believe that students develop mathematical understanding by "receiving clear, comprehensible, and correct information about mathematics procedures and by having the opportunity to consolidate, automatize, and generalize the information they have received by practicing the demonstrated procedures" (Goldsmith & Schifter, 1997, 22-23).

Cognitively Guided Instruction.

Carpenter, Fennema, Franke, Levi, and Empson (1999) developed Cognitively Guided Instruction (CGI) as a framework for helping teachers understand and capitalize on students' intuitive mathematical thinking.

Carpenter et al. (1999) explain:

Over the past twenty years, we have learned a great deal about how children come to understand basic number concepts. Based on our own research, and the work of others, we have been able to map out in some detail how basic number concepts and skills develop in early grades…we have been working with primary grade teachers to help them understand how children's mathematical ideas develop. We have observed how much children are capable of learning when their teachers truly understand children's thinking and provide them an opportunity to build on their own thinking. We have also learned from teachers how important it is for them to have explicit knowledge of children's mathematical thinking. (p. xiv)

They maintain that it is imperative for teachers to understand that students do not always think about mathematical problems the way that adults do. They explain, "Initially, young children have quite different conceptions of addition, subtraction, multiplication, and division than adults do" (p. 1). While adults may view a mathematical problem in terms of the operation required for solving, "young children initially think of them in terms of the actions or relationships portrayed in the problems" (p. 2). In other words, in the eyes of children, not all addition or

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subtraction problems are the same. Carpenter et al. (1999) argue, "There are important distinctions between different types of addition problems and between different types of subtraction problems, which are reflected in the way that children think about and solve them" (p. 2). Initially, students solve problems by directly modeling the actions in the problems. "Over time, direct modeling strategies give way to more efficient counting strategies" (Carpenter et al., 1999, p. 3). Students increasingly utilize more efficient, fact-based strategies for representing and solving problems. The essence of CGI is that this progression is intuitive to children and, when given the opportunity, children are capable of constructing these strategies for themselves.

Carpenter et al. (1999) posit:

The thesis of CGI is that children enter school with a great deal of informal or intuitive knowledge of mathematic that can serve as the basis for developing understanding of the mathematics of the primary school curriculum. Without formal or direct instruction on specific number facts, algorithms, or procedures, children can construct viable solutions to a variety of problems. Basic operations of addition, subtraction, multiplication, and division can be defined in terms of these intuitive problems solving processes, and symbolic procedures can be developed as extensions of them. (p. 4)

Carpenter et al. (1999) identified eleven problem types for addition and subtraction word problems (based on the four basic classes). The distinct

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problem types represent different interpretations of addition and subtraction and are constructed by varying the unknown within each type. Table 2.1 illustrates this Classification of Word Problems (Carpenter et al., 1999, p. 12).

Table 2.1 *Classification of Word Problems*

Problem Type			
Join	*(Result Unknown)* Connie had 5 marbles. Juan gave her 8 more marbles. How many marbles does Connie have altogether?	*(Change Unknown)* Connie has 5 marbles. How many more marbles does she need to have 13 marbles altogether?	*(Start Unknown)* Connie had some marbles. Juan gave her 5 more marbles. Now she has 13 marbles. How many marbles did Connie have to start with.
Separate	*(Result Unknown)* Connie had 13 marbles. She gave 5 to Juan. How many marbles does Connie have left?	*(Change Unknown)* Connie had 13 marbles. She gave some to Juan. Now she has 5 marbles left. How many marbles did Connie give to Juan?	*(Start Unknown)* Connie had some marbles. She gave 5 to Juan. Now she has 8 marbles left. How many marbles did Connie have to start with?
Part-Part-Whole	*(Whole Unknown)* Connie has 5 red marbles and 8 blue marbles. How many marbles does she have?		*(Part Unknown)* Connie has 13 marbles. 5 are red and the rest are blue. How many blue marbles does Connie have?
Compare	*(Difference Unknown)* Connie has 13 marbles. Juan has 5 marbles. How many more marbles does	*(Compare Quantity Unknown)* Juan has 5 marbles. Connie has 8 more than	*(Referent Unknown)* Connie has 13 marbles. She

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	Connie have than Juan?	Juan. How many marbles does Connie have?	has 5 more marbles than Juan. How many marbles does Juan have?

In addition to presenting this Classification of Word Problems, Carpenter et al. (1999) describe relationships between children's solution strategies and problem structures. They reinforce, "The distinctions among problem types are reflected in children's solution processes…Over time, children's strategies become more abstract and efficient. Direct modeling strategies are replaced by more abstract Counting strategies, which in turn are replaced with number facts" (Carpenter et al., 1999, p. 15).

Teachers' beliefs about children's mathematical thinking are reflected in the practices they enact. CGI is based on children's intuitive use of strategies for solving problems and focuses on these strategies for reflection and discussion. Namely, CGI supports the implementation of tasks that promote reasoning and problem solving (Practice #2), use of mathematical representations (Practice #3), meaningful mathematical discourse (Practice #4), build procedural fluency from conceptual understanding (Practice#6) and use of student thinking (Practice #8).

Beliefs about the roles of students and teachers.

Teachers hold very different views about the roles and responsibilities of students and teachers in the classroom. Reform-oriented teachers believe that students learn best by doing and learning mathematics on their own and that it is

the responsibility of the teacher to facilitate the learning while co-constructing knowledge through problem solving, questioning, and discourse (Peterson et al., 1989). Traditional-oriented teachers, on the other hand, believe that it is the responsibility of the teacher to direct and control all classroom activities while the students are responsible for absorbing and processing given information. Teachers with this view typically demonstrate the process or provide information, facts, laws, or rules that the students should follow and allow students time to work independently (Thompson, 1984). Learning is fostered through memorization of procedures (Stipek, Givvin, Salmon, & MacGyvers, 2001).

Beliefs about what counts as evidence of mathematical understanding.

Thompson (1984) found that there was a sharp contrast among teachers about what constitutes evidence of mathematical understanding. For some teachers (traditional), a student's ability to verbalize and follow taught procedures to arrive at the correct answer was sufficient evidence of student understanding. For other teachers (reform-oriented), the ability to simply carry out procedures and calculate correct answers was insufficient. These teachers expected students to understand the logic underlying the procedures and "took as evidence of students' understanding their ability to integrate their knowledge of facts, concepts, and procedures so as to find solutions to a variety of related mathematical tasks" (Thompson, 1984, p. 120). These views of what constitutes mathematical understanding reflect the teachers' underlying conceptions of mathematics.

Sociomathematical norms.

Yackel and Cobb (1996) set it set forth sociomathematical norms as "a way of analyzing and talking about the mathematical aspects of teachers' and students' activity in the mathematics classroom" (p. 474). They differentiate these norms from general classroom social norms such as explaining and justifying thinking, sharing strategies, and collaborating. Sociomathematical norms, they contend, are intrinsic aspects of the classroom's mathematical microculture" (Yackel & Cobb, 1996, p. 474). They reflect mathematical beliefs and values. Sociomathematical norms are useful in framing reform-oriented teaching practices. Specifically, sociomathematical norms are evidenced by what a teacher expects from student explanations. These norms include: (1) Explanations that consist of mathematical arguments, not simply descriptions of procedures or summaries of steps. (2) Capitalizing on errors a valuable opportunities for discussion, exploration, and reconceptualization. (3) Understanding the relationships among multiple strategies. (4) Collaborative work that involves individual accountability and consensus reach through mathematical argumentation (Yackel & Cobb, 1996). These sociomathematical norms are embedded in the mathematical discourse of reform-oriented classrooms. Specifically, these norms are reflected in the Mathematics Teaching Practices (NCTM, 2014) in which teachers use and connect mathematical representations (Practice #3), facilitate meaningful mathematical discourse (Practice #4), pose purposeful questions (Practice #5), build procedural fluency

from conceptual understanding (Practice #6), and elicit and use evidence of student thinking (Practice #8).

Beliefs about instructional planning.

Lui and Bonner (2016) studied beliefs between mathematical knowledge, beliefs about teaching and learning mathematics, and instructional planning. They focused on constructionist beliefs and planning that is consistent with constructivist theories of learning given their assumption that "knowledge and beliefs dimensions are related and conceptually align with distinct traditions of instructional planning and practice" (Lui & Bonner, 2016, p. 4). Instructional planning, they argue, can be seen as a mediator between what one intends to teach and what on actually teaches. Philipp (2007) supports the assumption that knowledge and beliefs influence instructional planning and that those beliefs are related to teachers' underlying conceptions about mathematics. Morris, Heibert, and Spirzer (2009) found that teachers had the ability to identify learning goals for their students, but did not use that information to inform instructional planning. They were also able to identify students' errors, but struggled to use the information to take the next instructional steps (Heritage, Kim, Vendlinski, & Herman, 2009).

Teachers who view mathematics as learning a collection of procedures saw little need for planning (Thompson, 1984) while teachers with a more contemporary view of mathematics "regarded the careful and thorough preparation of their lessons as an essential first step towards ensuring the quality

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of instruction" (Thompson, 1984, p. 120). It appears, Lui and Bonner (2016) concluded, "that teachers make choices while planning instruction among a variety of available pedagogical approaches, and these choices are based on a combination of professional knowledge and individual beliefs about teaching and learning" (p. 4)

Beliefs about curriculum

Teachers beliefs are key mediators in curriculum implementation (Fullan, 1993). Unfortunately, there is often a misalignment between the intended curriculum, the implemented curriculum, and the attained curriculum (Cuban, 1993). It is clear that the way teachers implement reform curriculum relates to the alignment of their beliefs (Hollingsworth, 1989).

The development of teachers' beliefs.

Understanding how beliefs are formed can help us understand how they may change (Goldin et al., 2009). Beliefs generate from previous events or episodes which are held in the episodic memory and serve to filter the understanding of subsequent events (Nespor, 1987). Pajares (1992) explains, "These images help teachers make sense of new information but also act as filters and intuitive screens through which new information and perceptions are sifted" (p. 324). Maab and Schloglmann (2009) describe a consensus that "beliefs, attitudes, and values are the consequence of an evolutionary process that involves all of an individual's experiences with mathematics throughout their entire life" (p. vii). Another important aspect of belief formation is the influence of

culture (Barkatsas & Malone, 2005). Hoyles (1992) describes belief formation as being situated and constructed from the interactions of activity, context, and culture. Therefore, teachers' beliefs about mathematics or mathematics teaching and learning are influenced by factors such as school, grade level, and students (Philipp, 2007). Similarly, Goldin et al. (2009) argue, "The process of sense making and the genesis of beliefs go hand in hand" (p. 9). Barkatsas and Malone (2005) found that the main influences on teachers' beliefs about the nature of mathematics were prior school experiences and personal world-views while the main influences on teachers' beliefs about teaching and learning mathematics were his or her school and teaching experiences.

> Specifically, Wilkins explains (2008):
>
> Some teachers who have higher content knowledge believe that since they were successful as a result of more traditional instruction that such methods are effective for their students—they tend to teach how they were taught. On the other hand, teachers who were less successful with mathematics as a child may empathize with their students and be more willing to try something different in hopes of sparing their students of similar negative experiences. (p. 157)

These influences highlight the important role that teachers' own school experiences play in the formation of their beliefs about the nature of mathematics and mathematics teaching and learning.

The impact of teachers' own school experiences.

In addition to mathematics teachers' beliefs, there are many other factors that influence instructional decision making including teachers' own experiences in school (Thompson 1984, 1985). Beliefs about teaching are well established by the time students get to college. These beliefs are developed during what Lortie (1975) refers to as the *apprenticeship of observation* (Lortie, 1975). During the many hours spent in K-12 education classrooms, future teachers develop ideas about what it means to be an effective teacher and how students should behave.

Pajares (1992) describes the challenge these beliefs present to teacher educators:

Preservice teachers are insiders. They need not redefine their situation. The classrooms of college education, and the people and practices in them, differ little from classrooms and people they have known for years. Thus, the reality of their everyday lives may continue largely unaffected by higher education, as may their beliefs. For insiders, changing conceptions is taxing and potentially threatening. These students have commitments to prior beliefs, and efforts to accommodate new information and adjust existing beliefs can be nearly impossible. (p. 323)

The reality is that "teachers, who must be agents of change, are products of the system they are trying to change" (Piazza, 1996, p. 54). In fact, most students who chose to pursue a career in education have a positive identification with

teaching which "leads to a continuity of conventional practice and reaffirmation, rather than challenge, of the past" (Pajares, 1992, p. 323).

The mathematical experiences that teachers had in school shape their beliefs about the nature of mathematics and mathematics teaching and learning. Philipp (2007) argues that the beliefs or feelings that students take away from learning mathematics in school are at least as important as the knowledge they gain of the subject. As students are learning mathematics, they are also forming beliefs about what mathematics is, its value, how it is learned, who should learn it, and what mathematical understanding entails (Philipp, 2007). Philipp (2007) explains that the emotional responses students experience while learning mathematics and the attitudes and beliefs that are developed linger well into adulthood and have important implications for teachers. In fact, a crucial experience or influential teacher likely serves as an inspiration, even a template, for a teacher's own teaching practices (Nespor, 1987).

Pajares (1992) expands on the potentially negative consequences of this replication of practice:

Episodic memories and construction of times in the past result in inappropriate representations and reconstructions in the present. Evaluations of teaching and teachers that individuals make as children survive nearly intact into adulthood and become stable judgments that do not change, even as teacher candidates grow into competent

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professionals, able, in other contexts, to make more sophisticated and informed judgments. (p. 324)

As Lortie (1975) put it, they are left with the belief that "what constituted good teaching then constitutes it now" (p. 66).

As noted previously, teachers also form their conceptions about the nature of mathematics as students. Unfortunately, many elementary teachers form negative beliefs about mathematics and may unintentionally pass them on to their students. Philipp (2007) traces this negative affect toward mathematics to teachers' experiences as learners of mathematics. Together with teachers' successes and failures in mathematics, these experiences influence how teachers interpret and deal with future events, including the instructional practices that they enact (Wilkins, 2008).

Knowledge

Wilkins (2008) argues that simply taking more mathematics courses or being good at mathematics is insufficient to meet the demands of teaching mathematics. Teachers, he insists, must have the necessary background to effectively teach mathematics in a way that promotes mathematical understanding.

In identifying the knowledge elements that are necessary to teach Shulman (1986) explains:

To think properly about content knowledge requires going beyond knowledge of the facts or concepts of a domain. It requires understanding

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the structures of the subject matter…[which] include both substantive and the syntactic structures. The substantive structures are the variety of ways in which the basic concepts and principles of the discipline are organized to incorporate its facts. The syntactic structures of a discipline is the set of ways in which truth or falsehood, validity or invalidity, are established. (p. 9)

Shulman (1986) identified Subject Matter Knowledge (SMK), Pedagogical Content Knowledge (PCK), and Curricular Knowledge (CK) as the knowledge elements that are necessary to teach. Teachers' SMK refers to the amount of knowledge in the mind of the teacher. "The teacher need not only understand that something is so; the teacher must further understand why it is so, on what grounds its warrant can be asserted, and under what circumstances our belief in its justification can be weakened and even denied" (Shulman, 1986, p. 9). The notion of PCK requires a shift in teacher understanding from being able to understand the subject matter for themselves to being able to clarify the subject matter in ways that can be understood by students (Shulman, 1986). Shulman characterizes PCK as "that special amalgam of content and pedagogy that is uniquely the province of teachers" (Shulman, 1986, p. 8). It, Shulman (1996) argues, "goes beyond subject matter knowledge to knowledge for teaching and includes "an understanding of what preconceptions that students of different ages and backgrounds bring with them to the learning" (p. 9) and knowledge "of students' misconceptions and their influence on subsequent learning" (p. 10). It is

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the complex knowledge that teachers must possess to make mathematics

accessible to all children (Philipp, 2007).

Research has found that when teachers have conceptual understanding of

mathematics, instruction is influenced in a positive way (Fennema & Franke,

1992). Unfortunately, many teachers lack conceptual understanding (Ma, 2010),

thus, rely less on conceptual knowledge and more on procedural knowledge

(Thanheiser, Browning, Edson, Whitacre, Olanoff, & Morton, 2014). There is, in

fact, consistent evidence that most teachers of young children lack the

knowledge elements that are necessary to teach (Clements, Copple, Hyson,

2002; Copley & Padron, 1999).

Knowledge and Beliefs

While beliefs are more influential than knowledge and greater predictors of

behavior (Nespor, 1987; Ernest, 1989), it is important to consider knowledge and

beliefs together when studying teachers' beliefs. Thompson (1992) insists, "To

look at research on mathematics teachers' beliefs and conceptions in isolation

from research on mathematics teachers' knowledge will necessarily result in an

incomplete picture" (p. 131). Knowledge and beliefs are, in fact, interwoven

(Pajares, 1992). "Beliefs may be dependent on the existence or, perhaps, the

absence of knowledge" (Cooney & Wilson, 1993, p. 150). For example, a

teachers' mathematical knowledge may lead to a belief about how mathematics

is best taught (Wilkins, 2008). While Ernest (1989) explains that knowledge is the

cognitive outcome and beliefs is the affective outcome, Thompson (1992) argues

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against attempting to distinguish between teachers' knowledge and teachers' beliefs. Instead, "researchers should investigate teachers' conceptions encompassing both beliefs and any relevant knowledge—including meanings, concepts, propositions, rules, or mental images—that bears on the experience" (Thompson, 1992, p. 261).

Conflicting Beliefs and Practices

Wilkins (2008) found that, for the majority of teachers, beliefs and practice were consistent. However, beliefs are not always consistent with instructional practices (Barkatsas & Malone, 2005; Ernest, 1989; Pajares, 1992; Thompson, 1992). Ernest (1989) offers three possible explanations for these inconsistencies including the depth of espoused beliefs and the extent to which they are integrated with knowledge and beliefs, teachers' consciousness of beliefs and extent to which the teacher reflects on practice, and social context. Barkatsas and Malone (2005) attribute the inconsistencies to three major causes: classroom situations, prior experiences, and social norms. They explain that "a single element in the classroom situation, or the influence of societal and parental expectations, and teaching social norms can affect teaching practice to a greater extent than the teacher's espoused beliefs" (Barkatsas &Malone, 2005, p. 86). The various influences force teachers to prioritize among competing, and sometimes conflicting, values which result in beliefs about mathematics and mathematics teaching being overshadowed by more general educational priorities (Skott, 2001). Raymond (1997) found that inconsistencies arose between beliefs and practice because of contextual factors such as scarcity of

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resources, time constraints, students' behavior, and concerns over standardized tests.

Hoyles (1992) found that when situating beliefs within the circumstances and constraints of particular settings the apparent inconsistencies between teachers' beliefs and actions are reconciled. In other words, inconsistencies cease to exist when teachers' thinking and context are better understood.

Pajares (1992) echoes this advice stating:

Researchers must study the context-specific effects of beliefs in terms of these connections. Seeing educational beliefs as detached from and unconnected to a broader belief system, for example, is ill-advised and probably unproductive…When carefully conceptualized, when educational beliefs and their implications are seen against the backdrop of a broader belief structure, inconsistent findings may become clearer and more meaningful. (p. 326-327)

Philipp (2007) proposes that when studying teachers' and their beliefs researchers should "assume that the inconsistencies exist only in our minds, not within the teachers, and would strive to understand the teachers' perspectives to resolve the inconsistencies" (p. 276).

Mathematics Teachers' Beliefs as Barriers to Reform

Mathematics teachers' beliefs may play either a facilitating or an inhibiting role in reform efforts (Handal & Herrington, 2003). Teachers beliefs and values that are contrary to constructivism act as barriers to reform in mathematics

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education (Piazza, 1996). Specifically, "Teachers who held conceptions of teaching based on transmission were unlikely to align to the goals of the Standards and therefore continued to teach traditionally" (Handal & Herrington, 2003, p. 64). It is important to understand that teachers do not enact traditional, transmission-oriented practices because they are unconcerned with students' learning, but rather because of their mistaken beliefs about the nature of mathematics and mathematics teaching and learning (Battista, 1994). Compounding this obstacle is the finding that "teachers often assimilate new ideas to fit their existing schemata instead of accommodating their existing schemata to internalize new ideas" (Philipp, 2007, p. 261). Reform initiatives call on teachers to change the content of what is taught, the way they view mathematics teaching and learning (Battista, 1994) and require major commitments from the teacher (Philipp, 2007). "If mathematics teachers' beliefs are not congruent with the beliefs underpinning an educational reform, then the aftermath of such a mismatch can affect the degree of success of the innovation as well as the teachers' morale and willingness to implement further innovation" (Handal & Herrington, 2003, p. 60).

Demands of reform.

As noted, educational reform efforts impose new demands on the already demanding job of teaching. Reform initiatives require teachers to adopt new roles and take on new responsibilities that are often very demanding. They have to align with a new way of teaching (Handal & Herrington, 2003) and undergo a process of unlearning and then learning again (Mousley, 1990). Reform may

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even ask teachers to change deeply held beliefs requiring them to desert the familiar for the unknown, which is a challenging task (Gootenboer, 2008).

The demands of reform efforts often awaken a variety of concerns within reluctant teachers. Fuller's (1969) hierarchy of teacher concerns is useful in framing the concerns teachers face when asked to implement reform initiatives. The hierarchy consists of teachers' self-concerns, task concerns, and impact concerns. Self-concerns are those concerns that teachers have about their ability to successfully undertake the demands of the new reform. Task concerns relate to daily duties of a teacher's job—time constraints, resource scarcity, and student concerns. Impact concerns are the concerns teachers hold about the consequences of the change on student learning.

Efficacy beliefs, those beliefs about one's ability/capacity to accomplish a task, have a dynamic and complex interaction with teacher concerns (Charalambous & Philippou, 2010). Efficacy beliefs impact task and impact concerns and teachers' personal concerns impact efficacy beliefs about reform implementation. Teachers with low efficacy display intense task concerns (Ghaith & Shaaban, 1999), while teachers with high efficacy are more concerned with the impact of the reform on students (McKinney, Sexton, & Meyerson, 1999). Teachers with high efficacy beliefs have been found to be more willing to adopt/experiment with new teaching approaches and materials (Ghaith & Yaghi, 1997).

Charalambous & Philippou (2010) explain how efficacy beliefs and teacher concerns may affect reform efforts:

Teachers who were more comfortable with pre-reform approaches tended to be more critical of the reform, exhibited more intense concerns about their capacity to manage the reform, and were more worried about its consequences on student learning. Consequently, these findings suggest that reform initiatives might fail when ignoring teachers' beliefs about their capacity to use pre-reform approaches. This failure of reform is because asking teachers to move beyond their comfort and safe zone—a zone they have probably reached after long effort and experimentation—requires investing time and effort, hence aggravating the already complex work of teaching. Without providing teachers with systematic and sustained support, teachers might resist the proposed reform, simply because of their comfort with already tested and tried approaches. (p. 14)

In short, addressing teacher concerns is an essential step toward ensuring the success of reform efforts. "The more teachers struggle with the logistics inherent in implementing the reform, the more they consider the reform a potential threat to student learning and the more they are inclined to abandon it in favor of other (pre-reform) approaches" (Charalambous & Philippou, 2010, p. 14). Teachers need support in overcoming these concerns if they are to see positive impacts on student learning and, thus, value in reform efforts.

Handal (2003) sums up the importance of considering the demands reform efforts place on teachers:

In brief, the teaching job places great external demands on decisions that teachers have to make rapidly, in isolation, and in widely varied circumstances. These demands put teachers in the position of resorting to practicality and intuition as indispensable resources for survival in the profession. These demands, in turn, favor the development of beliefs about what works and what does not in a classroom. At the same time, it seems that teachers generate their own beliefs about how to teach in their school years and these beliefs are perpetuated in their teaching practice. Thus, educational beliefs are passed on to the students. (pp. 49-50)

Dominant Cultural Beliefs as Barriers to Reform

Even when teachers' beliefs about mathematics and mathematics teaching and learning match those underlying curricular reform, the traditional nature of the educational system often makes enacting their progressive beliefs difficult (Handal, 2003). "Unfortunately, the prevailing view of educators and the public at large is that mathematics consists of set procedures and that teaching means telling students how to perform those procedures" (Batista, 1994, p. 463). Ball (1997) argues that progressive teachers are often afraid of how parents and administrators will view their reform efforts and are put in the position of defending the things that they are trying even before they feel comfortable with them. This resistance places a burden on reform-oriented teachers because the

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system itself does not encourage change, but rather acts "as a vehicle to reproduce traditional mathematical beliefs" (Handal, 2003, p. 50).

Changing Teachers Beliefs

It is unlikely that teachers can modify their teaching practices to align with reform efforts without changing their beliefs (Fullan & Stiegelbauer, 1991). Compounding the barriers to reform is the finding that educational beliefs are resistant to change (Pajares, 1992).

Philipp (2007) insists:

Teacher educators and professional developers must better understand not only what beliefs teachers hold but also how they hold them, because the ways that teachers hold their beliefs affect the extent to which existing beliefs can be challenged. Two impediments to changing teachers' beliefs are concern for the well-being of children that often inhibits teachers' willingness to challenge students and difficulty in overcoming the classroom challenges that derive from moving beyond their role as the teacher as one whose job it is to tell students how to be successful. (p. 281)

It is evident that changing one's beliefs is not normally the first option chosen (Goldin et al., 2009). The way beliefs are developed and held suggests that they may not be responsive to change through cognitive strategies including critical evaluation, external examination, and logical review (Grootenboer, 2008). Given the dynamics of teachers' beliefs, researchers and teacher educators must

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understand that beliefs do not change as a result of argumentation or reason but rather through a "conversion or gestalt shift" (Nespor, 1987, p. 321). Grootenboer (2008) explains that for belief change to occur a teacher must both review the episodes that generated the belief and create new experiences where the desired belief is successful. Additionally, for belief change to occur a context in which it is emotionally safe to do so must be established (Goldin et al., 2009).

The relationships between teachers' beliefs and practice are complex; each influences the other. Fennema et al. (1996) found that "there was no consistency in whether a change in beliefs preceded a change in instruction or vice versa" (p. 423). Some teachers' beliefs change before practice, and others change practice before their beliefs change (Philipp, 2007). Guskey (1986) describes a process in which teachers implement an instructional change, students succeed, and teacher beliefs change. Barkatas and Malone (2005) also found that teachers change their beliefs in light of classroom experience and when they see value in terms of student outcomes. Philipp (2007) suggests that exposure to mathematics teaching and learning practices may change teachers' beliefs and knowledge. In fact, teachers' beliefs and practices are likely to change when they learn about children's mathematical thinking.

The role of reflection.

Since beliefs serve as filters through which new ideas are perceived, it is essential for teachers to be challenged to reflect upon their beliefs. Teachers

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need systematic guidance in developing the skills for critical reflection and self-appraisal (Barkatsas & Malone, 2005).

> Philipp (2007) poses a quandary that is important for teacher educators to consider:
>
> If beliefs are lenses through which we humans view the world, then beliefs we hold filter what we see; yet what we see also affects our beliefs—creating a quandary: How do mathematics educators change teachers' beliefs by providing practice-based evidence if teachers cannot see what they do not already believe? The essential ingredient for solving this conundrum is reflection upon practice. When practicing teachers have opportunities to reflect upon the innovative reform-oriented curricula they are using, upon their own students' mathematical thinking, or upon other aspects of their practices, their beliefs and practices change. (p. 309)

The need for reflection is apparent in Thompson's (1984) findings that differences in teachers' beliefs seemed to be related directly to differences in their reflectiveness. Reflectiveness in teaching can attribute to the integratedness of conceptions and the consistency between professed views and instructional practice (Thompson, 1984). When beliefs are formed through reflection teachers "gain possible insights into possible sources of her students' difficulties and misconceptions, thus becoming aware of the subtleties inherent in the content" (Thompson, 1984, p. 123). When teachers are not reflective "their beliefs seem to be manifestations of unconsciously held views or expressions of verbal

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commitment to abstract ideas that may be thought of a part of a general ideology of teaching" (Thompson, 1984, p. 124). It is especially important to challenge the beliefs of teachers who feel that they were successful learning mathematics from more traditional methods so that they reflect on the effectiveness of these methods for *all* children (Wilkins, 2008).

Accomplishing the Goals of Reform

"Teachers are those who ultimately decide the fate of any educational enterprise" (Handal & Herrington, 2003, p. 65). Therefore, for reform efforts to be successful, teachers must hold beliefs that are compatible with the innovation. "It is unfair—and unproductive—merely to demand that teachers see and teach mathematics in a different way" (Battista, 1994, p. 470). For reform to find large scale success, misalignments between reform efforts and teacher beliefs must be identified, analyzed, and addressed (Handal & Herrington, 2003).

Ernest (1989) explains:

Such reforms depend to a large extent on institutional reform: changes in the overall mathematics curriculum. They depend even more essentially on individual teachers changing their approaches to the teaching of mathematics. Teaching reforms cannot take place unless teachers' deeply held beliefs about mathematics and its teaching and learning change. (p. 99)

Curriculum change is a complex process and it is evident that any successful reform will take into account teacher beliefs about the intended, the implemented,

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and the attained curriculum (Handal & Herrington, 2003). Philipp (2007) conjectured, "The most lasting change will result from professional development experiences that provide teachers with opportunities to coordinate incremental change in beliefs with corresponding change in practice" (p. 281). Once mathematics teachers understand and believe in the reform, they will lead the way in ensuring its success (Goldin et al., 2009).

Through this study I will seek to meet Thompson's (1984) challenge: "In a quest to understand better how teachers' conceptions mediate and interact with contextual factors, there is a need to examine the continuing development of stable patterns of beliefs over time and under different conditions" (p. 125). The results of this study will assist teacher educators and researchers in better understanding the influence a STEAM setting has on mathematics teachers' beliefs and practices related to the nature of mathematics and mathematics teaching and learning. The findings may potentially inform future professional development, research, and reform efforts in the field of mathematics education.

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CHAPTER 3

METHODOLOGY

This research project investigated the enacted practices and beliefs about the teaching and learning of mathematics held by elementary mathematics teachers situated in a STEAM (Science, Technology, Engineering, Arts, Mathematics) school. This chapter provides a description of the site and sample selection, procedures, measurement instruments, and data analysis.

Research Questions

Specifically, the research questions are:

- What are the beliefs about the teaching and learning of mathematics held by elementary mathematics teachers situated in a STEAM school?

- How does teaching in a STEAM school influence the enacted practices and beliefs of teachers about teaching and learning mathematics?

Site Selection

When selecting the site for this study, I chose to use purposeful sampling to gain information-rich cases to study in depth (Patton, 1990). Patton (1990) refers to the method of purposeful sampling that I employed as *homogeneous sampling*. This method focused the study and reduced variation. I selected a new

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STEAM elementary school as the site for the study. In the fall of 2016, the local school district opened a new elementary school with a focus on STEAM instructional approaches. The new school is located in the rapidly growing eastern portion of the county. New attendance lines were drawn which reassigned students from two existing schools within the district. The student population also includes students who were previously home-schooled or attended private school. In the first year (2016-2017), the school housed approximately 300 students in pre-kindergarten through fourth grade. The racial demographics of the student population are 1% Asian, 22% African American/Black, 3% Hispanic/Latino, 68% White, and 6% two or more races. Thirty-two percent of the students receive free or reduced lunch. A new middle school with a common focus and student make-up shares the cafeteria and the gym. A new STEAM high school is under construction and will open in August 2017. The three new schools are part of the district's vision for a STEAM "pipeline." The district's vision for STEAM is to engage students in pre-kindergarten through twelfth grade in solving real world problems through a transdisciplinary approach to learning focused on Science, Technology, Engineering, Arts, and Mathematics.

This site provided the opportunity to learn a great deal about the enacted practices and beliefs about the teaching and learning of mathematics held by elementary mathematics teachers situated in a STEAM school. I selected this site, as opposed to others like it, because given that it was a new school, I had the opportunity to investigate the enacted practices and beliefs about the

teaching and learning of mathematics held by elementary mathematics teachers situated in a STEAM school during their first year of teaching in this setting.

The school has 25 certified staff members (1 pre-kindergarten teacher, 3 kindergarten teachers, 4 first grade teachers, 3 second grade teachers, 3 third grade teachers, 3 fourth grade teachers, 1 physical education teacher, 1 music teacher, 1 art teacher, 1 media specialist, 1 guidance counselor, 1 instructional coach, 1 assistant principal, and 1 principal). All certified staff members received initial training on STEAM instructional approaches and writing STEAM units during a four-day workshop in July 2016. The focus of the training was on conceptualizing STEAM as a transdisciplinary approach to learning that focuses on problem solving. Additionally, the training outlined STEAM instructional approaches that prioritize problem solving, authentic tasks, inquiry, process skills, student choice, and technology integration. The teachers were informed that they were expected to design and implement two STEAM units during the first year (one in the fall semester and one in the spring semester). They were given flexibility with the district's instructional units and pacing guides to accommodate a transdisciplinary approach. During the summer training, grade level teams and academic arts teachers began generating ideas for their first semester STEAM units. Professors from Clemson University worked with the teachers to ensure that the problem scenarios were authentic and transdisciplinary. When school began in August, the teachers continued to work in their grade level teams to design their first semester STEAM units. The classroom teachers also collaborated with the academic arts teachers to design

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infused lessons to complement the STEAM units. Each grade level implemented a STEAM unit during the first semester of the 2016-2017 school year. The teachers were also encouraged to use the STEAM instructional approaches (problem solving, authentic tasks, inquiry, process skills, student choice, and technology integration) in all areas of their teaching. In October 2016, the consultants from Clemson reviewed and provided feedback on the first semester units. Also, the consultants conducted a site visit where they observed teachers at different points in the implementation of their units and provided direct feedback to the teachers. Time was provided during early release days in November and December 2016 for teachers to plan their second semester STEAM units. The instructional coach assisted in these planning sessions. The teachers also worked in their weekly Professional Learning Communities (PLC) to plan their units. In February 2017, the Clemson consultants reviewed the second semester STEAM units, conducted a site visit, and provided feedback to the teachers. Teachers were provided with resources and materials for their STEAM units through PTA grants aimed at supporting the STEAM vision. It is also important to note that the school has one-to-one Chromebooks in kindergarten through fourth grades. A district instructional technologist worked with the teachers two times a month throughout the school year to support meaningful technology integration.

Participant Selection

I conducted a case study to investigate the research questions. A case study involves a bounded integrated system with working parts (Stake, 1995).

This case is bound to one school and involved kindergarten through fourth grade mathematics teachers as participants. The selection of a case study design enabled the researcher to provide detailed descriptions of the beliefs of a smaller number of teachers by relying upon rich data sets that include a combination of observations, interviews, surveys, and artifacts collected over a period of time and triangulated. These rich data sets are important for theory building and enable researchers to consider interrelationships in the complex work of teaching (Jacobson & Kilpatrick, 2015). In this study specifically, the data enabled the researcher to investigate the relationships between teachers' beliefs, enacted practices, and experiences in a STEAM school.

I used the form of purposeful selection known as *criterion sampling* to select the participants for the study (Patton, 1990). All of the kindergarten through fourth grade mathematics teachers at the school were given the opportunity to participate in the study. However, only seven of the teachers elected to participate. This provided a sample size of n=7. The participants include two self-contained kindergarten teachers, two self-contained first grade teachers, one self-contained second grade teacher, one departmentalized third grade teacher (teaches three classes of mathematics), and one departmentalized fourth grade teacher (teaches three classes of mathematics). Selecting all of the teachers that meet the same criteria (mathematics teachers) provides quality assurance to this study. Four of the teachers are new to the district while the remaining three transferred from other schools within the district. The interview process was designed to select teachers who hold beliefs and have the capacity

to learn and implement instructional approaches that are in line with the district's vision of STEAM. However, it is important to note that over half of the teachers live in neighborhoods that are in proximity to the school.

The demographic characteristics of the participants were collected using online surveys providing the number of years of teaching experience, highest degree level, certification area(s), and grade(s) taught. The teachers were also asked to briefly describe their teaching experiences, including experiences with STEAM and teaching mathematics. Each participant's responses are summarized below. All names are pseudonyms to ensure anonymity of the participants.

Jennifer has ten years of teaching experience and currently teaches kindergarten. She has a bachelor's degree and is certified in Early Childhood Education. She has experience teaching mathematics in pre-kindergarten and kindergarten. This is her first year teaching in a STEAM school.

Lillian, who currently teaches first grade, has ten years of teaching experience. During her career, she has taught first, second, and third grades. She has also served as a Title I Facilitator/Instructional Coach for the district and spent the past year working as a Curriculum Specialist focusing on writing and revising the district's primary (kindergarten, first, and second grade) mathematics units. She has a master's degree and is certified in Early Childhood Education and Administration. Additionally, she has received extensive training in arts

integration and taught at an arts infused school for four years. She reported that this is her first experience teaching in a STEAM school.

Missy currently teaches fourth grade mathematics and has twelve years of teaching experience. She is certified in Early Childhood and Elementary Education and has a master's degree. She has experience teaching mathematics in kindergarten, first, and fourth grades. She also has experience working with the third, fourth, and fifth grade mathematics curriculum in the district. This is her first year teaching in a STEAM school.

Rebecca, who currently teaches kindergarten, has six years of teaching experience. She has a master's degree and is certified in Early Childhood and Elementary Education. She has experience teaching mathematics in kindergarten and first grade. This is her first year teaching in a STEAM school.

Sarah currently teaches third grade mathematics. She has four years of teaching experience in kindergarten and first grade. She has a bachelor's degree and is certified in Early Childhood, Elementary Education, and Special Education. She reported being a model teacher for personalized learning and has experience writing mathematics curriculum and assessments for her previous district. While this is her first year teaching in a STEAM school, she has used STEAM aspects in her classroom before "with many PBL units or projects."

Stephanie, who currently teaches first grade, has four years of teaching experience. She has experience teaching mathematics in pre-kindergarten and first grade. She is certified in Early Childhood and Elementary Education and is

currently pursuing her master's degree in Administration. This is her first year teaching in a STEAM school.

Tiffany, who currently teaches second grade, has over thirty years of teaching experience. While she has taught mathematics in all elementary grades, this is her first experience teaching in a STEAM school. She has a master's degree and is certified in Early Childhood and Elementary Education.

Procedures

I received permission to conduct this study from the local school district and the University of South Carolina's Instructional Review Board. To conduct research within the school district, I submitted the *Research Request* form to the Chief Academic Officer in the district and the principal of the school. This request included a description of the purpose of the study, proof of IRB approval, confidentiality statements, and an explanation of how the results of the study will be used. This information is required by the district to protect individual rights of students and staff in the school system and to avoid interference with the instructional programs. I also received consent from the developers of the survey instrument that was used in the study.

Upon approval of the proposal, I distributed the Invitation to Participate to all of the mathematics teachers. The Invitation to Participate (see Appendix A) included a teacher informed consent statement, procedures for the study, risks and benefits of taking part in the study, a confidentiality statement, a statement

about the voluntary nature of the study, the institutional affiliation of the researcher, the contact information for the researcher, and the subject's consent.

Data Collection Methods

According to Jong and Hodges (2015), conceptions are "measurable through a combination of surveys, interviews, artifacts, and observations" (p. 408). I, therefore, conducted a mixed-methods study to investigate the relationships between teachers' beliefs, enacted practices, and experiences in a STEAM school. Mixed-methods studies combine qualitative (i.e., interviews) and quantitative (i.e., MECS) data collection measures. By nature, mixed-methods studies increase researchers' understanding of a given phenomenon by exploring convergences in findings (Kidder & Fine, 1987) and enable researchers to combine "empirical" precision with "descriptive" precision (Onwuegbuzie & Leech, 2005).

The data collection for this study took place over a six-month period beginning in September 2016 and concluding in February 2017. I employed several data collection methods to gain answers to the research questions. There were two administrations of the Mathematics Experiences and Conceptions Survey (MECS) (Jong & Hodges, 2013). Through this survey, I was able to observe changes in teachers' beliefs about mathematics alongside factors in a STEAM setting that may influence those beliefs. Given that researchers must draw inferences from what people say or do to measure beliefs (Pajares, 1992), I utilized semi-structured interviews and classroom observations. I conducted two interviews (one in September 2016 and one in January/February 2017) with each

participant. The interview questions were designed to uncover the beliefs that the teachers hold about the teaching and learning of mathematics and how experiences in a STEAM setting influence those beliefs. I also conducted two observations for each participant during the data collection phase of the study. The aim of the observations was to gain information about the enacted practices of the teachers. I used the Reformed Teaching Observation Protocol (RTOP) (Piburn, M. Sawada, D., Falconer, K., Turley, J., Benford, R., & Bloom, I., 2000) to assess the degree to which the mathematics teaching was "reformed" and to identify any changes that occurred in classroom practice as a result of teaching mathematics in a STEAM school. Additionally, I conducted two "Scoop" collections. Each collection period spanned ten consecutive instructional days, one collection period was conducted in September 2016 and one collection period was conducted in January 2017. I collected classroom documents and artifacts including instructional materials, student work, assignments, formal classroom assessments, and photographs. The documents and artifacts provided additional information about the enacted practices of the teachers. Finally, I collected, through the pre-STEAM and STEAM surveys, demographic information such as participant gender, teaching experiences (including previous experiences with STEAM education), certification area, highest degree earned, and years of teaching experience. These data collection methods provided information that I can use to better understand the beliefs of mathematics teachers in a STEAM setting and their relationship to enacted practices.

Measurement Instruments

Mathematical Experiences and Conceptions Survey (MECS).

The MECS (Jong & Hodges, 2013) was designed as a way to quantitatively measure outcomes for pre-service elementary school teachers (PSTs) conceptions over time in order to understand the evolution of conceptions for teaching mathematics. Specifically, the MECS instrument was designed to "understand the development of elementary pre-service teachers' (PSTs) attitudes about mathematics, beliefs about mathematics, and dispositions toward reform mathematics teaching and learning" (Jong, Hodges, Royal, & Welder, 2015, p. 25). Jong and Hodges (2015) use *conceptions* as an overarching term to include attitudes, beliefs, and dispositions. Further, the MECS was designed to measure each of the three sub-constructs (attitudes, beliefs, and dispositions) alongside common experiences contextualized to specific points in the teacher education programs. Jong and Hodges (2015) explain, "These experiences are used in an attempt to explain current conceptions, alongside any changes seen in sub-constructs of conceptions throughout the teacher education program" (p. 408).

There are four versions of the MECS including MECS-M1 (administered at the beginning of mathematics methods coursework), MECS-M2 (administered at the end of mathematics methods coursework), MECS-S (administered at the completion of student teaching), and MECS-Y1 (administered at the completion of first year(s) of full-time teaching). Each version of the MECS contains the

same set of items for the sub-constructs (beliefs, attitudes, and dispositions), with contextualized experience items reflecting relevant experiences at particular points in teacher education that are specific to each version. The identical sub-construct items enable the researcher to avoid a form of single-method bias and measure growth over time. The MECS instruments consist primarily of six-point Likert-scale items (1 = strongly disagree, 2 = disagree, 3 = somewhat disagree, 4 = somewhat agree, 5 = agree, and 6 = strongly agree). The MECS also includes institution questions, field experience questions, and oral response questions. Jong and Hodges (2015) explain, "The combined set of items draws attention toward PSTs enjoyment of and inclination to see mathematics as a worthwhile endeavor from both teaching and learning perspectives" (p. 411).

Jong and Hodges (2015) argue, "The MECS conceptual model has a strong theoretical foundation grounded in the literature on conceptions about mathematics teaching and learning to experiences known to influence those conceptions" (p. 410). The strengths of this instrument make it a valuable instrument for this study. To conform to the parameters of this study and measure the experiences of in-service teachers practicing in a STEAM setting, I made some alterations to the MECS-Y1 instrument. First, I removed the institutional questions. I also edited the wording of the ST1 and ST2 sections to read, "Overall, my teaching experiences have provided me experiences with" as opposed to "Overall, my teaching experiences *this year* provided me experiences with." I labeled these altered sections *TE1* and *TE2*. I edited questions two and three in both surveys to reflect the South Carolina College- and Career-Ready

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Standards for Mathematics and the South Carolina College and Career-Ready Mathematics Process Standards as opposed to the Common Core State Standards and the Mathematical Practice Standards. Next, for MECS-preSTEAM, I edited the wording of the FE1 section to read "Please answer the following questions in regards to your previous experiences teaching mathematics" as opposed to "Please answer the following questions in regards to your experiences *teaching mathematics this year*." When necessary, I edited questions in this section to align with the new wording. I labeled this section *TE3*. I also deleted the FE2 and FE3 sections as they were not relevant to this study. Additionally, I deleted the OR1, OR2, and OR3 questions for the survey. I used the OR2 and OR3 questions in my semi-structured interviews. For the MECS-STEAM version of the instrument, I edited the TE1, TE2, and TE3 sections of the MECS-preSTEAM instrument to reflect experiences relevant to teaching mathematics in a STEAM setting. I also added a Demographic Information section to the MECS-preSTEAM and MSCS-STEAM. I used these sections to collect demographic information such as participant gender, teaching experiences (including previous experiences with STEAM education), certification area(s), and years of teaching experience. Finally, I entered the surveys into Google Forms for ease of sharing and completion by participants (see Appendix B and Appendix C). The participants had access to and were familiar with Google forms and they provided ease of sharing within the organization. It is important to note that items for the sub-constructs (beliefs, attitudes, and dispositions) remained identical. The identical sub-construct items

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enable the researcher to avoid a form of single-method bias, measure growth over time, and maintain the integrity of the instrument.

The MECS—preSTEAM (see Appendix B) was administered to each participant in the initial data collection phase of the study (September 2016) and the MECS—STEAM (see Appendix C) was administered in the final data collection phase of the study (January/February 2017). I posted the links to the forms in the shared Google Classroom one week prior to the submission deadline. For this study, I focused on the *Beliefs About Mathematics* sub-construct. This sub-construct is aimed at teachers' "beliefs about the nature of mathematics and their understanding about its role (Welder, Hodges, & Jong, 2011, p. 2118). The MECS *Beliefs About Mathematics* sub-construct consists of nine items that are rated using a six-point Likert-scale (1 = strongly disagree, 2 = disagree, 3 = somewhat disagree, 4 = somewhat agree, 5 = agree, and 6 = strongly agree). The negatively stated items on the surveys were reverse coded (1 = 6, 2 = 5, 3 = 4, 4 = 3, 5 = 2, 6 = 1). Higher ratings indicate productive beliefs toward reform-oriented mathematics. I used the qualitative measures as the primary source of data and triangulated that data with data from the surveys.

Semi-structured interviews.

"Interviewing gives us access to the observations of others. Through interviewing we can learn about places we have not been and could not go and about settings in which we have not lived" (Weiss, 1994, p. 1). I conducted semi-structured interviews to explore teachers' beliefs about teaching and learning

mathematics, perceptions about how teaching in a STEAM school influences

those beliefs, and how beliefs and experiences in a STEAM setting influence the

instructional practices they employ. Each teacher in the study was interviewed

twice, once in October 2016 and once in January/February 2017. The initial

interview focused on teachers' existing beliefs related to mathematics teaching

and learning and their perceptions of how teaching in a STEAM school may

influence those conceptions and, in turn, their enacted practices. The final

interview focused on how the teachers perceived the influence that teaching in a

STEAM setting had on their beliefs about teaching and learning mathematics as

well as their enacted practices. This line of inquiry is essential given that

teachers' perspectives on their practice may help to explain apparent

contradictions between their espoused beliefs and enacted practices (Jacobson

& Kilpatrick, 2015). The interviews were semi-structured with common questions

asked of all teachers to provide consistency across teachers. Follow-up

questions were asked based on individual teachers' responses.

Table 3.1 *Initial interview questions*

What makes a good mathematics teacher?
What makes a good mathematics student?
How do you define mathematical proficiency?
In what ways do you think students most effectively learn mathematics?
Imagine you walked into a classroom and saw the "best" teacher teaching mathematics.
What do you see happening in the classroom? What is the teacher doing? What are the students doing?
How do you anticipate your experiences teaching in a STEAM setting will influence your beliefs about mathematics teaching and learning?
How do you anticipate your experiences teaching in a STEAM setting will influence the instructional practices you select when teaching math?

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Table 3.2 *Final interview questions*

What makes a good mathematics teacher?
What makes a good mathematics student?
How do you define mathematical proficiency?
In what ways do you think students most effectively learn mathematics?
Imagine you walked into a classroom and saw the "best" teacher teaching mathematics.
What do you see happening in the classroom? What is the teacher doing?
What are the students doing?
How do you perceive that your experiences teaching in a STEAM setting have influenced your beliefs about mathematics teaching and learning?
How do you perceive that your experiences teaching in a STEAM setting have influenced the instructional practices you select when teaching math?

While these questions offered a good starting point for the semi-structured interviews, I was intentional about remaining open to reforming and adding to them throughout the research process. As Glesne (2011) explains, "Questions may emerge in the course of interviewing and may add to or replace pre-established ones" (p. 102). Additionally, interviews can be useful in providing information that was missed during an interview and in checking the accuracy of observation (Maxwell, 2013). All of the interviews were audio taped and transcribed.

Observations.

"Although interviewing is often an efficient and valid way of understanding someone's perspective, observation can enable you to draw inferences about this perspective that you couldn't obtain by relying exclusively on interview data" (Maxwell, 2013, p. 103). Therefore, in addition to interviews, I observed each participant once during the initial phase of data collection (October 2016) and

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once during the final phase of data collection (January/February 2017). Data were collected through classroom observations to examine the degree to which the mathematics instruction was "reformed" and to identify any changes that occurred in classroom practice as a result of teaching mathematics in a STEAM school. I used the Reformed Teaching Observation Protocol (RTOP) (Piburn et al., 2000) (see Appendix D) as an observational tool. The RTOP was designed, piloted, and validated by the Evaluation Facilitation Group of the Arizona Collaborative for Excellence in the Preparation of Teachers. It was designed, in part, to adhere to the reform teaching practices advocated by the National Council of Teachers of Mathematics (Sawada, Piburn, Turley, Falconer, Benford, Bloom, & Judson, 2000). Specifically, "The RTOP provides an operational definition of what is meant by 'reformed teaching.' The items arise from rich research-based literature that describes inquiry-oriented, standards-based teaching practices in mathematics and science" (Sawada et al., 2000, p. 1).

The RTOP is composed of five subtests: *Lesson Design and Implementation*, *Content* (*Propositional Knowledge*), *Content* (*Procedural Knowledge*), *Communicative Interactions*, and *Student/Teacher Relationships,* each with five items for a total of 25 items. *The Lesson Design and Implementation* subset is designed to capture a model for reform teaching.

Sawada et al. (2000) explain:

It describes a lesson that begins with recognition of students' prior knowledge and preconceptions, that attempts to engage students as

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members of a learning community, that values a variety of solutions to problems, and that often takes its direction from ideas generated by students. (p. 8)

The second subset, *Content*, was divided into two parts, *Propositional Knowledge* and *Procedural Knowledge*. The Propositional Knowledge component was designed to assess the quality of the content of the lesson. The *Procedural Knowledge* component was designed to capture the understanding of inquiry. Finally, the *Classroom Culture* was designed to assess the climate of the classroom. Together, these twenty-five items are intended to capture the full range of reformed teaching. Each item is scored on a Likert-scale from 0 (not observed) to 4 (very descriptive) of the classroom lesson. Because quality is determined at the lesson level, the length of each observation depends on the length of the lesson being observed. At the conclusion of the observed lesson, the observer rates the lesson, teacher, and classroom on each of the 25 characteristics. RTOP scores may range from 0 to 100. The RTOP is designed to be used by a trained observer and can be employed at any level from kindergarten through university. The use of the protocol requires observers with deep discipline-specific content knowledge who have completed training and co-observed classrooms or videos to develop the consistent use of the tool.

The RTOP has been deemed through research to be both valid and reliable for observing teachers in Grades K–12 science and mathematics classrooms. The construct validity indicators published for the RTOP (Sawada et al., 2000) suggests that the instrument succeeded in measuring the intended teaching

quality constructs (all R^2s >.75). The instrument also demonstrated predictive validity estimating that the RTOP can successfully predict growth in children's conceptual understanding of mathematics and number sense (all correlations between RTOP and normalized gains of children have been .88 or higher). The measure has also proven to have inter-rater reliability when observers undergo training (.954).

For this study, I used the RTOP Training Guide (Sawda et al., 2000) and online resources to prepare myself for using the RTOP for the observations. I then entered the protocol into a Google doc (see Appendix D) and a Google form (see Appendix E). In the Google doc, I recorded detailed field notes for each question during the observation. In the Google form, I entered each question with a Likert-scale from 0 (not observed) to 4 (very descriptive) of the classroom lesson. I referred to the field notes and completed this form immediately following each observation. Sawada et al. (2000) advises, "The whole lesson provides contextual reference for rating each item" (p. 2). A score of 0 was recorded for an item if the characteristic never occurred in the lesson. If the characteristic did occur, even once, a score of 1 or higher was recorded. A score of 4 was recorded for an item only when the item was "very descriptive" of the lesson. Sawada et al. (2000) note, "Ratings do not reflect the number of times an item occurred, but rather the degree to which that item was *characteristic* of the lesson observed" (p. 2).

To assist in the data analysis process, I aligned the twenty-five items in the RTOP with the *Eight Mathematics Teaching Practices* (NCTM, 2014) that I

employed as a framework for reform-oriented teaching practices. Table 3.3

displays this alignment.

Table 3.3 *Eight Mathematics Teaching Practices and RTOP item alignment*

Establish Mathematics Goals to Focus Learning
6. The lesson involved fundamental concepts of the subject. 14. Students were reflective about their learning.
Implement Tasks that Promote Reasoning and Problem Solving
1. The instructional strategies and activities respected students' prior knowledge and the preconceptions therein. 3. In this lesson, student exploration preceded formal presentation. 4. This lesson encouraged students to seek and value alternative modes of investigation or of problem solving. 10. Connections with other content disciplines and/or real world phenomena were explored and valued. 12. Students made predictions, estimations, and/or hypotheses and devised means for testing them. 13. Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures. 24. The teacher acted as a resource person, working to support and enhance student investigations. 25. The metaphor "teacher as listener" was very characteristic of this classroom.
Use and Connect Mathematical Representations
4. This lesson encouraged students to seek and value alternative modes of investigation or of problem solving. 11. Students used a variety of means (models, drawings, graphs, symbols, concrete materials, manipulatives, etc.) to represent phenomena. 10. Connections with other content disciplines and/or real world phenomena were explored and valued. 16. Students were involved in the communication of their ideas to others using a variety of means and media.
Facilitate Meaningful Mathematical Discourse
2. The lesson was designed to engage students as members of a learning community. 5. The focus and direction of the lesson was often determined by ideas originating with students. 8. The teacher had a solid grasp of the subject matter content inherent in the lesson. 15. Intellectual rigor, constructive criticism, and the challenging of ideas were valued. 16. Students were involved in the communication of their ideas to others using a variety of means and media.

18. There was a high proportion of student talk and a significant amount of it occurred between and among students.
19. Student questions and comments often determined the focus and direction of classroom discourse.
20. There was a climate of respect for what others had to say.
23. In general, the teacher was patient with students.
24. The teacher acted as a resource person, working to support and enhance student investigations.
25. The metaphor "teacher as listener" was very characteristic of this classroom.

Pose Purposeful Questions

14. Students were reflective about their thinking.
15. Intellectual rigor, constructive criticism, and the challenging of ideas were valued.
17. The teacher's questions triggered divergent modes of thinking.
18. There was a high proportion of student talk and a significant amount of it occurred between and among students.
19. Student questions and comments often determined the focus and direction of classroom discourse.
20. There was a climate of respect for what others had to say.
23. In general, the teacher was patient with the students.
24. The teacher acted as a resource person, working to support and enhance student investigations.
25. The metaphor "teacher as listener" was very characteristic of this classroom.

Build Procedural Fluency from Conceptual Understanding

3. In this lesson, student exploration preceded formal presentation.
7. The lesson promoted strongly coherent conceptual understanding.
9. Elements of abstraction (i.e., symbolic representations, theory building) were encouraged when it was important to do so.
14. Students were reflective about their learning.
18. There was a high proportion of student talk and a significant amount of it occurred between and among students.

Support productive struggle in learning mathematics

23. In general, the teacher was patient with the students.
24. The teacher acted as a resource person, working to support and enhance student investigations.
25. The metaphor "teacher as listener" was very characteristic of this classroom.

Elicit and Use Evidence of Student Thinking

1. The instructional strategies and activities respected students' prior knowledge and preconceptions.
5.The focus and direction of the lesson was often determined by ideas originating with students.
19. Student questions and comments often determined the focus and direction of classroom discourse.

20. There was a climate of respect for what others had to say.
25. The metaphor "teacher as listener" was very characteristic of this classroom.

Documents and artifacts.

To establish a thick description of classroom practice, I asked the participants to provide classroom documents and artifacts in a modified Scoop Notebook (Borko, Stecher, & Kuffner, 2007). These documents and artifacts enriched and provided a context for the data that was collected through the surveys, interviews, and observations.

Glesne (2011) explains:

Visual data, documents, artifacts, and other unobtrusive measures provide both historical and contextual dimensions to your observations and interviews. They enrich what you see and hear by supporting, expanding, and challenging your portrayals and perceptions. Your understanding of the phenomenon in question grows as you make use of the documents and artifacts that are a part of people's lives. (p. 89)

The analysis of the documents and artifacts collected in the Scoop Notebook provided a better understanding of teachers' beliefs and enacted practices and how they may be influenced by practicing in a STEAM environment.

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Scoop Notebook.

The Scoop Notebook is a data tool that uses classroom artifacts, teacher reflections, and related materials to characterize teachers' mathematics instruction on key dimensions of reform-oriented practice (Borko et al., 2007). The mathematics dimensions reflect the focus in the *Principles and Standards for School Mathematics* (NCTM, 2000) on students solving problems with multiple solutions and solution strategies, explaining and justifying their solutions, and communicating their mathematical thinking to others. The Scoop Notebook consists of artifacts of instructional practice (i.e., lesson plans, instructional practice, student work), photographs of classroom set-up and learning materials, and teacher responses to reflective questions that are "scooped" up over a set period and organized in a three-ring binder.

Borko et al. (2007) explain:

We developed the Scoop Notebook using an analogy to the way in which scientists approach the study of unfamiliar territory (e.g., the Earth's crust, the ocean floor). Just as scientists may scoop up a sample of materials from the place they are studying and take it back to their laboratories for analysis, materials can be "scooped" from classrooms (e.g., lesson plans, student work) to be examined later. (p. 3)

The Scoop Notebook consists of three main components including the project overview, teacher directions for collecting and labeling artifacts, and materials for assembling the notebook. The first section, the project overview, introduces

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teachers to the Scoop Notebook, highlights steps to follow before, during, and after the Scoop period, and provides a checklist for teachers to complete prior to submitting the notebook. The second section, teacher directions for collection and labeling artifacts, includes explicit directions about how to select the Scoop collection timeframe and class, complete the daily calendar, take photographs and complete the photo log, select student work, collect classroom artifacts and daily instructional materials, and a formal classroom assessment, label daily instructional materials and student work, and respond to daily reflection questions. The third section, materials for assembling the Scoop Notebook, includes the pre-Scoop, daily, and post-Scoop reflection questions, the daily calendar form, the photograph log, pocket folders for classroom artifacts (one for each day of the Scoop), and a pocket folder for student work and an assessment example. The Scoop Notebook also contains sticky notes for labeling artifacts and student work, a disposable camera, and cassette tape (Borko et al., 2007).

Artifacts.

The teachers are asked to collect three categories of artifacts: materials generated prior to class (i.e., lesson plans), materials generated during class (i.e., student work), and materials generated outside of class (i.e., student homework). Teachers are also encouraged to include any instructional materials not specified in the directions. Teachers are expected to label each artifact with a sticky note that indicates what the artifact is and the date. Additionally, teachers are asked to make entries into the daily calendar that briefly describe the length of the lesson, topic, and instructional materials that were used. Teachers are

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expected to take pictures of transitory evidence of instruction (e.g., work written on the board during class), the classroom layout and equipment, and materials that cannot be included in the notebook (e.g., posters prepared by students) and maintain a photograph log, identifying the subject and date of each picture (Borko et al., 2007).

Next, teachers are directed to select three different instances of student-generated work (e.g., in-class assignments, homework). For each instance of student-generated work, teachers are to collect three examples representing a range from high to low quality. Directions specify that the samples should be selected based on the quality of work, not on the ability of the students. This gives the researcher insight into teachers' judgments about the quality of student work. Additionally, teachers are directed to make an independent selection of student work for each assignment, rather than tracking the same students throughout the Scoop collection period. Teachers are to fill out and attach a "Teacher Reflections on Student Work" sticky note to each example of student work. On the sticky note, the teacher rates the quality of the work (high, medium, or low), describes the reason for giving that rating, and explains what they learned about the student's understanding of the material from the work (Borko et al., 2007).

Finally, teachers select and include a recent formal classroom assessment task (e.g., test, quiz, prompt or task) that is representative of the assessments they use.   They are also asked to include the scoring rubric or answer key, and

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examples of student responses to the assessment, if available (Borko et al., 2007).

Reflections.

In an attempt to gain information about a teachers' practice which artifacts alone might not provide (e.g., the context), teachers are asked to respond to three different sets of reflective questions.

First, teachers respond to pre-Scoop reflection questions about the typical lesson format, classroom context, and assessment strategies, as well as an overview of the lessons to be included in the Scoop Notebook. Next, during the Scoop period, teachers respond to daily reflection questions "as soon as possible" after completion of each lesson. Questions during this period ask the teachers to describe the lessons, including a discussion of if the learning objectives were met, modifications that were made to the original plan and modifications that are anticipated for the next day's lesson. Finally, after the conclusion of the Scoop period, teachers answer post-Scoop questions. These items include questions that ask teachers to explain how the series of lessons fit in with their long-term goals for students, whether this series of lesson was typical of their instruction, how well the Scoop Notebook portrays their instruction, and what other materials might be included to create a better portrayal (Borko et al., 2007).

The Scoop Notebook can be used as a tool to characterize classroom practices and as a tool for teacher professional development.

Modified Scoop Notebook.

For this study, I used a modified version of the Scoop Notebook as a tool to characterize the classroom practices of elementary mathematics teachers within a STEAM setting. I collected lesson plans, samples of student work, pictures of the classroom layout and materials, and transitory evidence of instruction (e.g., board work, anchor charts).

There were two ten day Scoop periods during the data collection phase of the study (one in September 2016 and one in January 2017). The teachers were asked to save lesson plans, pictures of classroom artifacts from the period (e.g., posters, writing on the board, classroom set-up and materials), one sample assessment, and three samples of student work (illustrating high, medium, and low quality of work) in a specified Google Drive folder. The samples of student work were to be selected based on the quality of work, not on the ability of the students. This provided insight into teachers' judgments about the quality of student work (Borko et al., 2000). I used these documents and artifacts as a compliment to the interviews and observations. They helped to further characterize classroom practice and examine the relationships between beliefs, enacted practices, and teaching in a STEAM setting.

Data Analysis

Maxwell (2013) explains, "Any qualitative study requires decisions about how the analysis will be done, and these decisions should inform, and be informed by, the rest of the design" (p. 104). I approached the data analysis

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portion of this case study with the goal of making a detailed description of the case and the setting. I began my data analysis immediately following the first administration of the MECS-preSTEAM and continued the analysis through the end of the study. The data were analyzed separately, but simultaneously and then compared to examine the relationships between beliefs, enacted practices, and experiences in a STEAM school (Strauss & Corbin, 1990). I used the qualitative measures as the primary source of data and triangulated that data with data from the surveys.

> Hatch (2002) effectively sums up the data analysis process for qualitative researchers:
>
> Data analysis is a systematic search for meaning. It is a way to process qualitative data so that what has been learned can be communicated to others. Analysis means organizing and interrogating data in ways that allow researchers to see patterns, identify themes, discover relationships, develop explanations, make interpretations, mount critiques, or generate theories. It often involves synthesis, evaluation, interpretation, categorization, hypothesizing, comparison, and pattern finding. It always involves what H. F. Wolcott calls "mind work". . . Researchers always engage their own intellectual capacities to make sense of qualitative data. (p. 148)

I processed the data that I collected by following the data analysis and coding procedures suggested by Creswell (2013). He suggests a process that involves

organizing the data, reading and memoing, describing, classifying, and interpreting data into codes and themes, interpreting the data, and representing and visualizing the data. Creswell (2013) describes the data analysis process as a spiral. He explains, "The process of data collection, data analysis, and report writing are not distinct steps in the process—they are interrelated and often go on simultaneously in a research project" (Creswell, 2013, p. 182). In this study, I engaged "in the process of moving in analytic circles rather than using a fixed linear approach" (Creswell, 2013, p. 182). I first organized my files into a Google Drive folder by instrument (i.e., "Missy pre-RTOP"). I then made a hard copy of all of the data including:

- MECS-preSTEAM (see Appendix B),
- RTOP preSTEAM field notes (see Appendix D),
- RTOP preSTEAM form (see Appendix E),
- initial interview transcripts,
- initial Scoop Notebooks,
- MECS-STEAM (see Appendix C),
- RTOP postSTEAM field notes (see Appendix D),
- RTOP postSTEAM form (see Appendix E),
- final interview transcript, and
- final Scoop Notebooks.

I approached the data analysis through the lens of reform-oriented beliefs and practices outlined in the literature in the field. Namely, I identified evidence of constructivist/reform-oriented beliefs and evidence of traditional/transmission-

oriented beliefs. I utilized the *Eight Mathematics Teaching Practices* (NCTM, 2014) as a framework for reform-oriented practices and identified evidence of each practice. I began the data analysis process by reading and memoing each piece of data to get a sense of the whole database. Following the advice of Agar (1980), I immersed myself in the details to get a sense of the whole before I broke it into parts. In the analysis of the interview transcripts, the observations, and the documents/artifacts I drew inferences from what participants said and did during the interviews and observations (Pajares, 1992) and considered the documents and artifacts in terms of form, function, and symbol within specific contexts (Glesne, 2011). I remained aware that "respondents answer questions in the context of dispositions (motives, values, concerns, needs) that researchers need to unravel to make sense out of the words that their questions generate" (Glesne, 2011, p. 102). I wrote memos, including phrases, ideas, or key concepts that occurred to me as I was reading, in the margins and under photographs. I then scanned the database to identify major organizing ideas and formed initial categories by reflecting on the larger thoughts presented in the data and looked for multiple forms of evidence to support each thought. Next, I moved into the spiral of describing, classifying and interpreting the data. I did this by forming codes. Through coding, I worked to build detailed descriptions, develop themes, and provide an interpretation in light of my own views and the views presented in the literature. Specifically, I coded evidence of constructivist/reform-oriented beliefs, evidence of traditional/transmission-oriented beliefs, and evidence of the *Eight Mathematics Teaching Practices* (NCTM, 2014). I developed the codes by

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"aggregating the text or visual data into small categories of information, seeking evidence for the code from different data bases being used in the study, and then assigning a label to the code" (Creswell, 2013, p. 184). I then developed a short list of codes and worked to reduce and combine them into themes. In establishing the codes, I searched for relationships between the data and created a thematic organizational framework that highlighted the data that applied to the research purpose. Once the codes were established, I continued to explore the relationships between the data by analyzing "how categorizations or thematic ideas represented by the codes vary from case to case, from setting to setting or from incident to incident" (Gibbs, 2007, p. 48). Creswell (2013) describes themes as "broad units of information that consist of several codes aggregated to form a common idea" (p. 186). Throughout the entire process, I looked for information in the data that would help me form a deep description of this particular case. Themes emerged from this process that were grounded in analysis and data. I then created a table for each theme and organized the quotes, artifacts, and classroom description under each theme.

Next, I engaged in interpreting, or making sense, of the data.

Cresswell (2013) explains:

Interpretation in qualitative research involves abstracting out beyond the codes and themes to the larger meaning of the data. It is a process that begins with the development of the codes, the formation of themes from

the codes, and then the organization of themes into larger units of abstraction to make sense of the data. (p. 187)

I linked the interpretation to the larger literature base and represented the data by packaging "what was found in text, tabular, and figure form" (Creswell, 2013, p. 187).

Establishing Trustworthiness

Establishing trustworthiness is an essential component of qualitative research (Lincoln & Guba, 1985; Glesne, 2011).

When selecting the methods to utilize in establishing trustworthiness for this study, I considered the questions posed by Lincoln and Guba (1985):

How can an inquirer persuade his or her audiences (including self) that the findings of an inquiry are worth paying attention to, worth taking account of? What arguments can be mounted, what criteria invoked, what questions asked, that would be persuasive on this issue? (p. 290)

Lincoln and Guba (1985) argue that the four criteria of credibility, transferability, dependability, and confirmability, must be met to generate confidence in the findings of a qualitative study. They further offer techniques for meeting each criterion. In this study, I employed several of these techniques to establish trust in the findings. To increase the probability of high credibility, I engaged in prolonged engagement, persistent observation, triangulation, and member checking. My role as the instructional coach at the school gave me the opportunity to engage with the participants on a daily basis.

Lincoln and Guba (1985) explain the importance of this prolonged engagement in establishing credibility:

The period of prolonged engagement is intended to provide the investigator an opportunity to build trust…it is a *developmental* process to be engaged in daily: to demonstrate to the respondents that their confidences will not be used against them; that pledges of anonymity will be honored; that hidden agendas, whether that of the investigator or of other local figures to whom the investigator may be beholden, are not being served; that the interests of the respondents will be served as much as those of the investigator; and that the respondents will have input into, and actually influence, the inquiry process. (p. 302)

The prolonged engagement was an essential component in establishing trust and rapport with the participants. Additionally, this technique helped me to learn the context and culture, and minimize distortions (Lincoln & Guba, 1985, Creswell, 2014). The persistent observation technique helped me to identify the characteristics and elements in the situation that were relevant to the research questions and focus on them in detail. The credibility of the study was strengthened by triangulation of different data collection methods (i.e. interviews, observations, artifacts, surveys).

Webb, Campbell, Schwartz, and Sechrest (1966) explain the power that triangulation has in making the data believable:

Once a proposition has been confirmed by two or more measurement processes, the uncertainty of its interpretation is greatly reduced. The most persuasive evidence comes through triangulation of measurement procedures. If a proposition can survive the onslaught of a series of imperfect measures, with all their irrelevant error, confidence should be placed in it. (p. 3)

This technique also proved useful in identifying and corroborating emerging themes in the data (Creswell, 2013). Additionally, I used the technique of member checking to gain the participants' views on the credibility of the findings. I provided thick descriptions of the case and the setting to increase the transferability. The use of purposeful sampling provides a data base that "makes transferability judgments possible on the part of potential appliers" (Lincoln & Guba, 1985, p. 316).

The techniques employed to demonstrate credibility, prolonged engagement, persistent observation, triangulation, and member checking, also strengthen the dependability of this study. Lincoln and Guba (1985) explain, "If it is possible using the techniques outlined in relation to credibility to show that a study has quality, it ought not be necessary to demonstrate dependability separately" (p. 317). Confirmability of the study was increased through a detailed

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description of the data collection and analysis methods as well as explanations of how and why decisions were made throughout the study.

Researcher Positionality

Clarifying researcher bias is another essential component of establishing trustworthiness (Merriam, 1988; Creswell, 2013). This clarification helps the reader understand the researcher's position and "any bias or assumptions that may impact the inquiry" (Creswell, 2013, p. 251). Inherent in qualitative research is the acceptance that researcher's bias and values impact the results of any study (Merriam, 1988). However, Peshkin (1998) argued that "one's subjectivities could be seen as virtuous, for bias is the basis from which researchers make a distinctive contribution, one that results from the unique configuration of their personal qualities, and joined to the data they have collected" (p. 18). My positioning as the former district mathematics coordinator and current instructional coach vis-à-vis the participants in the study may have impacted the results of the study. Through prolonged participation, I was able to build trust and rapport with the participants to overcome this challenge. Over time, we developed relationships in which they felt comfortable talking to me and being honest about their experiences, beliefs, and practices. Additionally, my professional and educational experiences in relation to the study topic were sure to influence my analysis and interpretation. I have thirteen years of experience in mathematics education as a teacher, mathematics interventionist, mathematics coach, district coordinator, and instructional coach. Over the years, I have extensively researched best practices in the field and developed a progressive

belief system that is in line with the current reform movement in mathematics education. I have extensively researched how teachers' beliefs are formed and how they influence enacted practices.

Limitations

This study has several limitations that are imposed by the setting. Situating the study in a STEAM elementary school limits the generalizability of the results to STEAM settings with kindergarten through fourth grade students. The study was also limited by the number of willing participants. Only seven out of the twelve mathematics teachers at the school agreed to participate in the study. The teachers who were not willing to participate cited time limitations and over commitment to other teaching activities as their primary reasons for not participating. It is also possible that my role as the instructional coach at the school may have deterred some teachers from participating. Additionally, when taken individually, certain components of the methodology are weak (i.e., surveys that rely on self-reported data). I argue, however, that together the elements form a powerful empirical evidence base for investigating how teaching in a STEAM setting influences teachers' enacted practices and beliefs about mathematics teaching and learning.

Delimitations

I selected the school and the context for this study, which constrains the study to one STEAM school. Additionally, I constrained the participants to kindergarten through fourth grade mathematics teachers. I also made specific choices about the methods I employed that further constrain the study. Namely, I

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chose to use an abbreviated version of the Scoop Notebook. I made this choice because I feared that requiring the full version would impose too many demands on the teachers and would influence their decision to participate. My selection of this particular school poses further constraints because of my role as the instructional coach. As an instructional coach, I am responsible for participating in professional learning communities, reviewing and providing feedback on lesson plans, facilitating professional development, modeling and observing lessons, and conducing "coaching conversations" with teachers. I also serve on the leadership team and maintain a close relationship with the administrators. While I do not hold an evaluative role, it is possible that teachers view me, to some extent, as an evaluator.

Summary

In Chapter 3, I outlined the methodology of this study in detail. Specifically, a description of the site and sample selection, procedures, measurement instruments, and data analysis is provided. I also provided a description of the techniques that were used to establish trustworthiness in the findings of the study.

CHAPTER 4

RESULTS

The purpose of this study was to understand the enacted practices and
beliefs about the teaching and learning of mathematics held by elementary
mathematics teachers situated in a STEAM (Science, Technology, Engineering,
Arts, Mathematics) school. The following research questions were addressed: (1)
What are the beliefs about the teaching and learning of mathematics held by
elementary mathematics teachers situated in a STEAM school? (2) How does
teaching in a STEAM school influence the enacted practices and beliefs of
teachers about teaching and learning mathematics? Multiple sources of data
were used, including surveys, observations, Scoop Notebooks, and semi-
structured interviews, to explore the research questions and triangulate the
findings.

Summary of Methodology

The MECS—preSTEAM (see Appendix B) was administered to each
participant in the initial data collection phase of the study (September 2016) and
the MECS—STEAM (see Appendix C) was administered in the final data
collection phase of the study (January/February 2017). For this study, I focused
on the *Beliefs About Mathematics* sub-construct. This sub-construct is aimed at

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teachers' "beliefs about the nature of mathematics and their understanding about its role" (Welder, Hodges, & Jong, 2011, p. 2118). The MECS *Beliefs About Mathematics* sub-construct consists of nine items that are rated using a six-point Likert-scale (1 = strongly disagree, 2 = disagree, 3 = somewhat disagree, 4 = somewhat agree, 5 = agree, and 6 = strongly agree). The negatively stated items on the surveys were reverse coded (1 = 6, 2 = 5, 3 = 4, 4 = 3, 5 = 2, 6 = 1). Higher ratings indicate productive beliefs toward reform-oriented mathematics. I used the qualitative measures as the primary source of data and triangulated that data with data from the surveys.

I observed each participant once during the initial phase of data collection (October 2016) and once during the final phase of data collection (January/February 2017). Data were collected through classroom observations to examine the degree to which the mathematics instruction was "reformed" and to identify any changes that occurred in classroom practice as a result of teaching mathematics in a STEAM school. I used the Reformed Teaching Observation Protocol (RTOP) (Piburn et al., 2000) (see Appendix D) as an observational tool. "The RTOP provides an operational definition of what is meant by 'reformed teaching.' The items arise from rich research-based literature that describes inquiry-oriented, standards-based teaching practices in mathematics and science" (Sawada et al., 2000, p. 1).

The RTOP is composed of five subtests: *Lesson Design and Implementation*, *Content* (*Propositional Knowledge*), *Content* (*Procedural Knowledge*), *Communicative Interactions*, and *Student/Teacher Relationships,*

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each with five items for a total of 25 items. Together, these twenty-five items are intended to capture the full range of reformed teaching. Each item is scored on a Likert-scale from 0, not observed, to 4, very descriptive, of the classroom lesson. A score of 0 was recorded for an item if the characteristic never occurred in the lesson. If the characteristic did occur, even once, a score of 1 or higher was recorded. A score of 4 was recorded for an item only when the item was "very descriptive" of the lesson. Sawada et al. (2000) note, "Ratings do not reflect the number of times an item occurred, but rather the degree to which that item was *characteristic* of the lesson observed" (p. 2).

To assist in the data analysis process, I aligned the twenty-five items in the RTOP with the *Eight Mathematics Teaching Practices* (NCTM, 2014) that I employed as a framework for reform-oriented teaching practices. Table 4.1 displays this alignment.

Table 4.1 *Eight Mathematics Teaching Practices and RTOP item alignment*

Establish Mathematics Goals to Focus Learning
6. The lesson involved fundamental concepts of the subject.
14. Students were reflective about their learning.
Implement Tasks that Promote Reasoning and Problem Solving
1. The instructional strategies and activities respected students' prior knowledge and the preconceptions therein.
3. In this lesson, student exploration preceded formal presentation.
4. This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.
10. Connections with other content disciplines and/or real world phenomena were explored and valued.
12. Students made predictions, estimations, and/or hypotheses and devised means for testing them.
13. Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures.
24. The teacher acted as a resource person, working to support and enhance student investigations.

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25. The metaphor "teacher as listener" was very characteristic of this classroom.

Use and Connect Mathematical Representations
4. This lesson encouraged students to seek and value alternative modes of investigation or of problem solving.
11. Students used a variety of means (models, drawings, graphs, symbols, concrete materials, manipulatives, etc.) to represent phenomena.
10. Connections with other content disciplines and/or real world phenomena were explored and valued.
16. Students were involved in the communication of their ideas to others using a variety of means and media.

Facilitate Meaningful Mathematical Discourse
2. The lesson was designed to engage students as members of a learning community.
5. The focus and direction of the lesson was often determined by ideas originating with students.
8. The teacher had a solid grasp of the subject matter content inherent in the lesson.
15. Intellectual rigor, constructive criticism, and the challenging of ideas were valued.
16. Students were involved in the communication of their ideas to others using a variety of means and media.
18. There was a high proportion of student talk and a significant amount of it occurred between and among students.
19. Student questions and comments often determined the focus and direction of classroom discourse.
20. There was a climate of respect for what others had to say.
23. In general, the teacher was patient with students.
24. The teacher acted as a resource person, working to support and enhance student investigations.
25. The metaphor "teacher as listener" was very characteristic of this classroom.

Pose Purposeful Questions
14. Students were reflective about their thinking.
15. Intellectual rigor, constructive criticism, and the challenging of ideas were valued.
17. The teacher's questions triggered divergent modes of thinking.
18. There was a high proportion of student talk and a significant amount of it occurred between and among students.
19. Student questions and comments often determined the focus and direction of classroom discourse.
20. There was a climate of respect for what others had to say.
23. In general, the teacher was patient with the students.
24. The teacher acted as a resource person, working to support and enhance student investigations.

25. The metaphor "teacher as listener" was very characteristic of this classroom.
Build Procedural Fluency from Conceptual Understanding
3. In this lesson, student exploration preceded formal presentation.
7. The lesson promoted strongly coherent conceptual understanding.
9. Elements of abstraction (i.e., symbolic representations, theory building) were encouraged when it was important to do so.
14. Students were reflective about their learning.
18. There was a high proportion of student talk and a significant amount of it occurred between and among students.
Support productive struggle in learning mathematics
23. In general, the teacher was patient with the students.
24. The teacher acted as a resource person, working to support and enhance student investigations.
25. The metaphor "teacher as listener" was very characteristic of this classroom.
Elicit and Use Evidence of Student Thinking
1. The instructional strategies and activities respected students' prior knowledge and preconceptions.
5.The focus and direction of the lesson was often determined by ideas originating with students.
19. Student questions and comments often determined the focus and direction of classroom discourse.
20. There was a climate of respect for what others had to say.
25. The metaphor "teacher as listener" was very characteristic of this classroom.

The RTOP scores, along with the detailed field notes, helped to develop a thick-rich description of the enacted practices for each participant. The data were also analyzed to identify themes in enacted practices as well as any changes that were observed in enacted practices.

I conducted semi-structured interviews to explore teachers' beliefs about teaching and learning mathematics, perceptions about how teaching in a STEAM school influences those beliefs, and how beliefs and experiences in a STEAM school influence the instructional practices they employ. Each teacher in the study was interviewed twice, once in October 2016 and once in

January/February 2017. The initial interview focused on teachers' existing beliefs related to mathematics teaching and learning and their perceptions of how teaching in a STEAM school may influence those conceptions and, in turn, their enacted practices. The final interview focused on how the teachers perceived the influence that teaching in a STEAM school had on their beliefs about teaching and learning mathematics as well as their enacted practices. The interviews were semi-structured with common questions asked of all teachers to provide consistency across teachers. Follow-up questions were asked based on individual teachers' responses. The interview data were used to develop thick-rich descriptions of the beliefs about mathematics teaching and learning and perceptions about the influence of teaching in a STEAM school for each participant. The data were also analyzed to identify themesin teachers' beliefs about mathematics teaching and learning as well as any changes that occurred in beliefs about mathematics teaching and learning.

Finally, Scoop Notebooks were collected. There were two ten day Scoop periods during the data collection phase of the study (one in September 2016 and one in January 2017). I used these documents and artifacts as a compliment to the interviews and observations.

Data analysis.

I approached the data analysis through the lens of reform-oriented beliefs and practices outlined in the literature in the field. Namely, I identified evidence of constructivist/reform-oriented beliefs and evidence of traditional/transmission-oriented beliefs. I utilized the *Eight Mathematics Teaching Practices* (NCTM,

2014) as a framework for reform-oriented practices and identified evidence of each practice. I began the data analysis process by reading and memoing each piece of data to get a sense of the whole database. Following the advice of Agar (1980), I immersed myself in the details to get a sense of the whole before I broke it into parts. In the analysis of the interview transcripts, the observations, and the documents/artifacts I drew inferences from what participants said and did during the interviews and observations (Pajares, 1992) and considered the documents and artifacts in terms of form, function, and symbol within specific contexts (Glesne, 2011). I remained aware that "respondents answer questions in the context of dispositions (motives, values, concerns, needs) that researchers need to unravel to make sense out of the words that their questions generate" (Glesne, 2011, p. 102). I wrote memos, including phrases, ideas, or key concepts that occurred to me as I was reading, in the margins and under photographs. I then scanned the database to identify major organizing ideas and formed initial categories by reflecting on the larger thoughts presented in the data and looked for multiple forms of evidence to support each thought. Next, I moved into the spiral of describing, classifying and interpreting the data. I did this by forming codes. Through coding, I worked to build detailed descriptions, develop themes, and provide an interpretation in light of my own views and the views presented in the literature. Specifically, I coded evidence of constructivist/reform-oriented beliefs, evidence of traditional/transmission-oriented beliefs, and evidence of the *Eight Mathematics Teaching Practices* (NCTM, 2014). I developed the codes by "aggregating the text or visual data into small categories of information, seeking

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evidence for the code from different data bases being used in the study, and then assigning a label to the code" (Creswell, 2013, p. 184). I then developed a short list of codes and worked to reduce and combine them into themes. In establishing the codes, I searched for relationships between the data and created a thematic organizational framework that highlighted the data that applied to the research purpose. Once the codes were established, I continued to explore the relationships between the data by analyzing "how categorizations or thematic ideas represented by the codes vary from case to case, from setting to setting or from incident to incident" (Gibbs, 2007, p. 48). Creswell (2013) describes themes as "broad units of information that consist of several codes aggregated to form a common idea" (p. 186). Throughout the entire process, I looked for information in the data that would help me form a deep description of this particular case. Themes emerged from this process that were grounded in analysis and data. I then created a table for each theme and organized the quotes, artifacts, and classroom description under each theme.

Next, I engaged in interpreting, or making sense, of the data.

Cresswell (2013) explains:

Interpretation in qualitative research involves abstracting out beyond the codes and themes to the larger meaning of the data. It is a process that begins with the development of the codes, the formation of themes from the codes, and then the organization of themes into larger units of abstraction to make sense of the data. (p. 187)

I linked the interpretation to the larger literature base and represented the data by packaging "what was found in text, tabular, and figure form" (Creswell, 2013, p. 187).

Establishing Trustworthiness

Establishing trustworthiness is an essential component of qualitative research (Lincoln & Guba, 1985; Glesne, 2011). In this study, I employed several techniques to establish trust in the findings. To increase the probability of high credibility, I engaged in prolonged engagement, persistent observation, triangulation, and member checking. My role as the instructional coach at the school gave me the opportunity to engage with the participants on a daily basis. The prolonged engagement was an essential component in establishing trust and rapport with the participants. Additionally, this technique helped me to learn the context and culture, and minimize distortions (Lincoln & Guba, 1985, Creswell, 2014). The persistent observation technique helped me to identify the characteristics and elements in the situation that were relevant to the research questions and focus on them in detail. The credibility of the study was strengthened by triangulation of different data collection methods (i.e. interviews, observations, artifacts, surveys). This technique also proved useful in identifying and corroborating emerging themes in the data (Creswell, 2013). Additionally, I used the technique of member checking to gain the participants' views on the credibility of the findings. I provided thick descriptions of the case and the setting to increase the transferability. The use of purposeful sampling provides a data

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base that "makes transferability judgments possible on the part of potential appliers" (Lincoln & Guba, 1985, p. 316).

The techniques employed to demonstrate credibility, prolonged engagement, persistent observation, triangulation, and member checking, also strengthen the dependability of this study. Lincoln and Guba (1985) explain, "If it is possible using the techniques outlined in relation to credibility to show that a study has quality, it ought not be necessary to demonstrate dependability separately" (p. 317). Confirmability of the study was increased through a detailed description of the data collection and analysis methods as well as explanations of how and why decisions were made throughout the study.

Chapter Organization

This study revealed four major findings in relation to the research questions: (1) Teachers in a STEAM school expressed similar and consistent beliefs about the teaching and learning of mathematics that are considered productive in light of reform efforts. (2) Teachers in a STEAM school enacted divergent practices. (3) Teaching in a STEAM school strengthens teachers' beliefs about the importance of integration and connecting mathematics to authentic, real world situations. (4) Teaching in a STEAM school influenced teachers' enacted practices in relation to situating mathematics in authentic, real world situations. These findings will be explained in depth in the following sections. Each finding was corroborated by multiple data sources, providing a more comprehensive understanding of the beliefs held by mathematics teachers

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situated in a STEAM setting about mathematics teaching and learning and the practices they enact as well as the influence that a STEAM setting has on teachers' beliefs and enacted practices.

This chapter consists of three sections. First, a thick-rich description is provided for each teacher. Second, the findings are presented in relation to each of the research questions. The third section includes a discussion of the findings.

Teacher Descriptions

The findings of this study exemplify the entire data set of seven teachers. Contrasting cases from the study were used to highlight consistency in teachers' beliefs and divergence in instructional practices. Merriam (1998) explains, "Comparative case studies involve collecting analyzing data from several cases" (p. 194). The cases of four teachers, Lillian, Rebecca, Stephanie, and Tiffany, were selected to represent the entire sample. Specifically, these teachers were selected because they exemplify the greatest divergence in practice. "A qualitative, inductive, multi-case study seeks to build abstraction across cases" (Merriam, 1998, p. 195). I approached the analysis of each case in this study with this goal in mind. Analysis of the data indicated that Lillian and Tiffany enacted reform-oriented teaching practices as framed by the *Eight Mathematics Teaching Practices* (NCTM, 2014) that aligned to their beliefs about mathematics teaching and learning. On the other hand, Stephanie and Tiffany enacted transmission-oriented teaching practices that were often in conflict with their beliefs.

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This section provides a thick-rich description of each teacher. It is included to give the reader a sense of who the teachers are—What do they believe? How is their practice characterized? Each description is presented in chronological order in an effort to highlight changes that occurred over the span of the study.

Lillian

Lillian, who currently teaches first grade, has ten years of teaching experience. During her career, she has taught first, second, and third grades. She has also served as a Title I Facilitator/Instructional Coach for the district and spent last school year working as a Curriculum Specialist focusing on writing and revising the district's primary (kindergarten, first, and second grade) mathematics units. She has a master's degree and is certified in Early Childhood Education and Administration. Additionally, she has received extensive training in arts integration and taught at an arts infused school for four years. She reported that this is her first experience teaching in a STEAM school.

MECS—preSTEAM survey responses.

Lillian's survey responses on the MECS--preSTEAM *Beliefs About Mathematics* sub-construct indicate that she holds beliefs about mathematics that are considered productive in light of reform efforts. Table 4.2 displays Lillian's survey responses.

Table 4.2 *Lillian's MECS--preSTEAM Beliefs About Mathematics sub-construct responses*

Item	MECS--preSTEAM
There is typically one way to solve a mathematics problem.	6
Doing mathematics involves analyzing multiple strategies for solving problems.	6
Mastering facts and developing skills for carrying out calculations is essential to knowing mathematics.	4
Mathematics is an attempt to know more about the world around us.	6
Mathematics involves making generalizations.	6
Mathematics is rarely used in society.	6
Mathematics involves constructing an argument.	6
Knowing mathematics is mostly about performing calculations.	6
Mathematics is essential to everyday life.	6

Description of Lillian's initial observation and accompanying RTOP scores.

Lillian began the initial observation lesson by providing the students with an opportunity to connect to their prior knowledge. She said, "Take a second to think about what we have been working on in math. Talk to your partner...go!" Once the students had an opportunity to share with their partners, Lillian discussed the mathematical goal of the lesson. She said, "We are going to solve word problems today. You are going to work with a partner to represent, solve, and explain the problem." Lillian presented a problem solving task to the students that was accessible, yet provided reasoning and problem solving opportunities to all of the students. The problem read: "There are 6 apples on the tree. Some apples are still green and 2 of the apples are red. How many apples are green?"

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Instead of providing a formal presentation of how to solve the problem, she allowed the students the opportunity to use their own reasoning strategies and methods for solving the problem. She also encouraged students to use a variety approaches to make sense of and solve the problem. She explained, "You can use whatever tools you have in front of you, but you have to prove your answer. You're going to solve, share with your partner, and then we're going to talk about it." The students had access to a variety of manipulatives and tools for representing problems and it was apparent that procedures were in place for the students to access the "tools" when they needed them. Students were expected to explain, clarify, justify, and elaborate on their thinking. At one point, Lillian reminded the class, "Don't forget that you have to be able to prove it to the whole group." At another point she prompted, "It's quiet in here. I should hear your voices explaining how you solved the problem and how you can prove it." As the students explored the task, she provided support by providing prompts and asking questions that built on students' thinking, made the mathematics visible, and held student accountable for explaining their thinking. For example, she prompted, "Okay, Max, tell me about your strategy." The following exchange demonstrates how she helped one student make his thinking visible:

Student: "Six."

Lillian: "Six what?"

Student: "Six green apples. I do it on my fingers."

Lillian: "Show me what you do on your fingers." (Student demonstrated.) "How could you represent that using a drawing?" (Student drew the illustration on the

dry erase board.) "I want you to practice drawing it so that you can see what you are doing."

She encouraged another student, "Mathematicians have to justify. Just saying, 'My brain told me' is not enough justification."

As Lillian was monitoring, she selected two students, John and Sophia, to share their strategies with the class. Each of the students was given the opportunity to project his/her work under the document camera and explain his/her strategy to the class. Figure 4.1 displays the students' approaches to solving the task and their corresponding explanations.
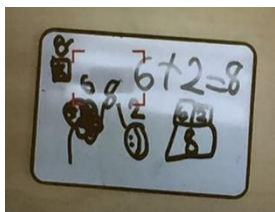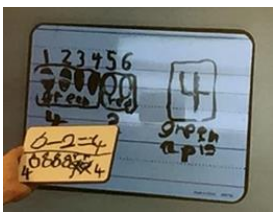
There are 6 apples on the tree. Some apples are still green and 2 of the apples are red. How many apples are green?	
John's strategy	Sophia's strategy
Student explanation: "There were six apples on the tree." (Pointed to the circle labeled "6.") Then there were two more apples." (Points to the circle labeled "2.") "Six plus two equals eight." (Points to the numbers in the equation.)	**Student explanation:** "I drew six circles for the six apples on the tree. Then I drew a box around two of the circles. I wrote 'green.' The rest of the apples had to be red. These are the red. There are four."

Figure 4.1 *Student approaches to the apple task*

After John shared his strategy with the class, Lillian encouraged the students to agree or disagree with his solution strategy and explain why. She instructed,

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"Talk with your partner about how your solution strategy is similar or different from John's." The students turned and shared with their partners. Lillian then asked one student who disagreed with John's solution to explain why he disagreed. The student explained, "There are 6 apples in all, not 8." The teacher then asked Sophia to share her strategy with the class. As Sophia explained her solution strategy, Lillian instructed the class to think about how the strategy was alike or different from John's strategy. John realized where the flaws in his thinking were and explained, "I thought that two apples were being added, but now I see that there were 6 apples in all. Two are green so four must be red." Another student added, "My strategy is like Sophia's because I had six apples and took two green ones away to get four apples." Lillian held up the student's representation in front of Sophia's to provide the students with the opportunity to connect the two representations.

This segment of the lesson demonstrates Lillian's use of mathematical discourse to engage "students in purposeful sharing of mathematical ideas, reasoning, and approaches, using varied representations" (NCTM, 2014, p. 35). While the correct solution was important, Lillian also placed value on the students' ability to explain and justify their strategies, listen to and critique the reasoning of others, and identify how different approaches are the same and how they are different. Further, she capitalized on a student's error by approaching it in a way that helped the students see that making mistakes is a natural part of learning and can often provide opportunities to deepen their learning.

Lillian's RTOP scores indicate that she enacted reform-oriented teaching practices in her initial observation. Table 4.3 provides Lillian's initial RTOP scores.

Table 4.3 *Lillian's initial RTOP scores*

Component	Pre-RTOP
Lesson Design & Implementation	19
Content—Propositional Knowledge	17
Content—Procedural Knowledge	20
Classroom Culture—Communicative Interactions	20
Classroom Culture—Student/Teacher Relationships	20
TOTAL	96

Description of Lillian's initial interview responses.

During the initial interview, Lillian expressed the belief that a "good" mathematics teacher is familiar with the standards and has an understanding of what his or her students need to know and be able to do. She explained, "It starts with knowing the standards …looking at the standard and thinking about from the standards what it is that my kids need to know." She also expressed constructivist beliefs about mathematics teaching and learning. She insisted, "I think you have to create opportunities for your students to experience…to come to their own understanding." She suggested that this might be accomplished by "digging through it [mathematics] deeply, by proving things and talking about things and explaining their thinking behind it." Her belief in the powerful role that mathematical discourse plays in mathematics teaching and learning was evident in her responses to the interview questions. She explained that children learn mathematics best by "doing and through talking about it and through

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representing problems." She continued, "[Talk plays] a major role. I think it's helping them, like, firm up their understanding and it's helping me see what they know."

Lillian also expressed beliefs about the roles of students and teachers in the mathematics classroom that are consistent with constructivist, reform-oriented, views. In the initial interview she explained, "A good math teacher isn't somebody who only just does all the talking and thinks that her kids are just going to basically memorize everything that she is saying and do it her way." She provided a description of what a teacher assuming the role of a facilitator might look like. She explained, "The teacher would be kind of like listening to what students were saying, stopping to ask for clarification, like, 'How do you do this?' or 'Tell me why you did this.'" Students, she explained, "would be probably working with partners and solving problems using tools like base ten blocks or counters depending on what they were doing."

In her discussion of students, she also described her beliefs about what constitutes mathematical proficiency and understanding. She expressed a balanced view of what constitutes mathematical proficiency.

She explained:

[Proficiency] would be kinda a combination of conceptual understanding and the procedural fluency. If they only understood the concept, but it took them, they had to do a strategy every single time for every single thing it would take forever and they wouldn't be efficient, but if they only just had

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certain things memorized and they didn't really know why they wouldn't really ever be able to apply that same understanding to other situations, so it wouldn't be totally proficient that way either. So, I think it's a blend.

She also expressed the belief that certain affective characteristics, such as perseverance, play an essential role in mathematical understanding and proficiency. She explained, "[Students] persevere working through a math problem, then they try different ways to answer it, they can talk about how they answered a question and how it relates…to some type of real life thing." Additionally, she defined mathematical proficiency as "being proficient with the standards."

In the initial interview, Lillian expressed optimism about the influence that STEAM instructional approaches might have on her mathematics teaching.

When asked how she believed that STEAM would influence her beliefs about mathematics teaching and learning and the practices she enacts she responded:

I hope that it becomes more of a combination of stuff and not just, like, here's our math time, here's our science time, here's our whatever time. I do hope it becomes more project based where we're, like, being able to tie it kind of all together so it's not quite so isolated. I feel like it's still kind of pretty isolated, um, so I'm hoping through, like the sea turtles project, we were able to weave some of it in. This was our first project so I didn't expect it to be perfect, but, um, I do hope it becomes more of, like, really

starting with a problem and, like, being able to use our math to solve

things in science or, you know, whichever subject. But definitely hope it

becomes more integrated.

MECS—STEAM survey responses.

Lillian's survey responses on the MECS--STEAM *Beliefs About*

Mathematics sub-construct indicate that she holds beliefs about mathematics

that are considered productive in light of reform efforts. There were no notable

changes between her MECS—preSTEAM ratings and her MECS—STEAM

ratings. Table 4.4 displays Lillian's survey responses.

Table 4.4 *Lillian's MECS--STEAM Beliefs About Mathematics sub-construct responses*

Item	MECS--STEAM
There is typically one way to solve a mathematics problem.	6
Doing mathematics involves analyzing multiple strategies for solving problems.	6
Mastering facts and developing skills for carrying out calculations is essential to knowing mathematics.	3
Mathematics is an attempt to know more about the world around us.	6
Mathematics involves making generalizations.	6
Mathematics is rarely used in society.	6
Mathematics involves constructing an argument.	6
Knowing mathematics is mostly about performing calculations.	6
Mathematics is essential to everyday life.	6

Description of Lillian's final observation and accompanying RTOP

scores.

Lillian's final observation lesson reflected teaching practices that were

consistent with the practices witnessed in the initial observation. Once again, she

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posed a problem solving task to the class. The problem read: "Ms. Elizabeth's class put 7 apples in the compost bin. Ms. Lillian's class put 8 more apples in the compost bin. How many apples are in the compost bin?" She encouraged students to use a variety of approaches to make sense of and solve the problem. Lillian instructed the students, "Take a second to read the problem to yourself. As you're reading you should be looking for clues and thinking, 'What is this problem even asking?'" She continued, "Think about what's happening and solve the problem with whatever strategy you need." As the students explored the task, Lillian monitored, posed questions, and selected students to share. She encouraged student-to-student construction of ideas instructing, "Turn toward your partner and explain how you solved the problem." It was evident in the student interactions that they were used to listening and critiquing the reasoning of others. They challenged each other's solutions asking, "How do you know?"

As she brought the class together, Lillian said, "I saw a lot of really interesting strategies. I saw a lot of people counting all of the apples. Did anyone do something different?" One student, Max, was selected to share his strategy. Lillian reminded the class, "As you're listening to these strategies you should be thinking about how these strategies work, if you agree or disagree, and how they relate to your strategy." As Max explained his strategy, Lillian facilitated his explanation by prompting with questions such as, "Where'd you get the 7? What part of the problem told you to get the 7? Hang on, so you said you had 7 on your fingers so you put 3 more, tell us about that." Through this series of questions the student was able to explain how he made a ten and then added the remaining

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five. Lillian prompted Max to make the mathematics visible, "Use the ten-frame so everybody can see in their head what you're talking about."

Lillian then asked, "Did anyone use another strategy?" Bailey was selected to share her solution strategy with the class. Lillian praised the class stating, "I can tell you are thinking really hard and asking each other questions so that it makes sense." Before Bailey began to explain her strategy, Lillian reminded the students, "We are being respectful, thinking in our head how the strategy works and how we can use it ourselves." Bailey then shared her strategy. She said (as she pointed to her drawing), "I had seven apples and then I counted eight more." Students were given an opportunity to share the connections that they saw between the strategies that were shared.

Once again, Lillian utilized a problem solving task to allow students the opportunity to explore and solve problems through the use of varied representations and solution strategies. She also served as a facilitator of mathematical discourse and helped students identify similarities and differences between different representations and solution strategies. It is important to note that Lillian presented a problem to the class that used the real names of first grade teachers and set the mathematics in an authentic, real world context that is reflective of a shared experience (composting).

Lillian's RTOP scores indicate that she enacted reform-oriented teaching practices in her final observation. Table 4.5 provides Lillian's final RTOP scores.

Table 4.5 *Lillian's final RTOP scores*

Component	Post-RTOP
Lesson Design & Implementation	19
Content—Propositional Knowledge	19
Content—Procedural Knowledge	19
Classroom Culture—Communicative Interactions	19
Classroom Culture—Student/Teacher Relationships	20
TOTAL	96

Description of Lillian's final interview responses.

During the final interview, Lillian reinforced her belief in the importance of mathematical discourse in stating, "[A good mathematics teacher is] patient, believes that there's value in listening to the rationale, there's value in justifying, there's value in talking." She added, "[Students best learn mathematics] when they're given real world situations that mean something to them."

Lillian also reinforced her belief in the role of the teacher as a facilitator. She described an ideal mathematics classroom in which "the teacher is checking in, making sure that each person is doing what they're supposed to be doing, but also pressing for further understanding, like, 'How did you get that?' 'How did you know to do that?'" She added, "I try really hard to model those types of questions when I'm talking to kids or conferencing with kids." Her beliefs about the roles of students also remained consistent. She explained, "The kids are analyzing a real world problem, the kids are talking about that problem, kids are solving that problem in different ways. Um, kids are talking about their solutions."

In her description of what constitutes mathematical understanding and proficiency she continued to emphasize the role of real world problems. She

insisted, "If they can't apply it to a real situation then they probably don't even really understand what it means."

She characterized mathematical proficiency as:

The ability to solve problems in diverse ways and justify those problems and listen to other people's justifications for theirs and think about yours. Like, making connections to other ways to solve it. Not thinking that there's just one way. Um, basically, being able to solve problems and understand how and why.

When asked about how teaching in a STEAM school has influenced her beliefs and practices concerning teaching mathematics she continued to reference her belief in the importance of using real world problems. She reflected, "I do think it encourages me to think harder about making connections across the curriculum…definitely real world and just thinking about, like, what the kid is getting from it."

Rebecca

Rebecca, who currently teaches kindergarten, has six years of teaching experience. She has a master's degree and is certified in Early Childhood and Elementary Education. She has experience teaching mathematics in kindergarten and first grade. This is her first year teaching in a STEAM school.

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MECS—preSTEAM survey responses.

Overall, Rebecca's survey responses on the MECS--preSTEAM *Beliefs About Mathematics* sub-construct indicate that she holds beliefs about mathematics that are considered productive in light of reform efforts. However, she did "somewhat disagree" with the statement, "Mathematics involves making generalizations." Table 4.6 displays Rebecca's MECS--preSTEAM *Beliefs About Mathematics* sub-construct responses.

Table 4.6 *Rebecca's MECS--preSTEAM Beliefs About Mathematics sub-construct responses*

Item	MECS-preSTEAM
There is typically one way to solve a mathematics problem.	5
Doing mathematics involves analyzing multiple strategies for solving problems.	5
Mastering facts and developing skills for carrying out calculations is essential to knowing mathematics.	4
Mathematics is an attempt to know more about the world around us.	5
Mathematics involves making generalizations.	3
Mathematics is rarely used in society.	6
Mathematics involves constructing an argument.	4
Knowing mathematics is mostly about performing calculations.	5
Mathematics is essential to everyday life.	6

Description of Rebecca's initial observation and accompanying RTOP scores.

Rebecca's initial observation lesson began with a read aloud. After reading the book to the entire class, Rebecca provided specific directions for each center rotation. In Center 1, "Write the Room," the students were to find the

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"fall pictures" placed around the room, count the number of objects on each picture, and record the number on the worksheet. In Center 2, the students worked with the teaching assistant to play a game in which they matched numbers to pictures. Center 3 included number puzzles for the students to work on the carpet. Rebecca worked with the students in Center 4. The students were divided into groups and dispersed into the centers. Every twelve minutes the students rotated into a new center until they had visited each center for the day.

Rebecca began the work with her groups by posing the following problem: "Rebecca went to the pumpkin patch and picked three pumpkins. She dropped one. How many are left?" Two students correctly responded, "Two!" Rebecca praised, "Good job!" Rebecca did not ask the students to explain their solution strategies. In fact, the culture supported students keeping their ideas to themselves as evidenced by the following exchange:

Student: "I know what six plus six is!"

Rebecca: "You do? What is it?"
Student: "Twelve!"

Rebecca: "Good." Hushes other students who are trying to join in the conversation reminding them, "Make sure you have a bubble in your mouth."

In an apparent rush to finish, Rebecca then helped the students add the number three to their number books. The following exchange is reflective of the work that was done with the teacher during each rotation.
Rebecca: "What is our number of the day?"

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Student: "Three!"

Rebecca: "Show me three fingers. (Students displayed three fingers.) "Now, open to page number three, please. We have the number 3, the word three, and three tally marks. Trace the number 3 and write the number 3 three times." (Paused as the students completed their pages.)

Rebecca: "We have an empty ten-frame. Remember, where do you start when you're filling in your ten-frame? Do you start at the bottom?"

Students: "No!"

Rebecca: "You start at the top." (The students copied the ten-frame into their books and then found all of the threes.)

Rebecca: "You have a little extra time so you can work on the cover of your book."

The students then rotated to their next center. Each group did the exact same thing and there was no indication of how students were grouped. At the end of the final rotation, Rebecca said, "Centers are over, put all center materials away and sit on the carpet." The students then watch the video and the song "The Number Three." The lesson closed with the following exchange:

Rebecca: "What did we work on today in math centers?"

Students: "Counting!"

Rebecca: "What do we call those things?"

Students: "Numbers!"

Rebecca: "What is our number of the day?"

Students: "Three!"

Rebecca: "Show me three fingers." (Students flashed three fingers.) "Clap three times." (Students clapped three times.) "What do you think our number is going to be tomorrow?"

Students: "Four!"

Rebecca: "Yes!"

These classroom episodes reflect the teaching practices that were observed during Rebecca's initial observation lesson. Rebecca dominated much of the conversation in both the whole group and small group settings. She posed questions that focused on correctness and did not prompt students to explain their mathematical thinking. Additionally, the teacher presented the representations (e.g. ten-frame, tally marks, fingers) and provided explicit procedures for how to construct the representations.

Her RTOP scores indicate that Rebecca did not enacted reform-oriented teaching practices in her initial observation. Table 4.7 provides Rebecca's initial RTOP scores.

Table 4.7 *Rebecca's initial RTOP scores*

Component	Pre-RTOP
Lesson Design & Implementation	2
Content—Propositional Knowledge	8
Content—Procedural Knowledge	2
Classroom Culture—Communicative Interactions	4
Classroom Culture—Student/Teacher Relationships	3
TOTAL	19

Description of Rebecca's initial interview responses.

In the initial interview, Rebecca expressed beliefs about mathematics teaching and learning that prioritize hands-on learning and the use of centers as a structure for mathematics instruction.

She explained:

I think what makes a good math teacher is someone who is willing to differentiate instruction to meet the needs of all kids and also use all different types of techniques to teach math skills…hands-on, audio, visual, whatever kids need to allow them to succeed. It needs to be in a center, you know, for a week or two and then assessment. If they still don't get it, reteach it or find a different way to allow them to work on the skill in a hands-on way.

Rebecca also expressed her belief that "good" mathematics instruction includes modeling and practice. She stated, "I think it needs to be visual and I think there needs to be modeling and then a lot of practicing."

Rebecca also shared her beliefs about the roles of the teacher and students in a mathematics classroom. She explained, "The teacher is differentiating, meeting the needs of all the kids. The students would all be on task and completing tasks that are appropriate for their abilities." Her response about problem solving in kindergarten revealed some conflicting beliefs about the roles of teachers and students.

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She stated:

> I feel in kindergarten you have to lead them to become problem solvers,
> but sometimes it's hard because it's really easy as a teacher to solve it for
> them because you get frustrated. But you have to let them, you know,
> grow and become problem solvers because it helps them in every single
> aspect of their lives.

On one hand, she expressed the belief in the role of students as problem solvers,
but, on the other hand, expressed doubts about kindergarteners' abilities to solve
problems and explained the desire to "solve it for them."

> When asked what constitutes mathematical proficiency, Rebecca
> responded:

> I would say that if a student is proficient in a skill that they, it means that
> they've mastered it, that they can complete a task independently to show
> that they have knowledge of that skill is and how to use the skill…being
> able to do it independently without the help or support of a peer or teacher
> would be proficient.

This response reveals the importance that Rebecca places on independence
when determining proficiency. She also described proficiency by stating, "I'd say
it's pretty much when you look at the standards across where they're at."
Additionally, Rebecca expressed the belief that mathematical understanding and
proficiency consists of certain affective characteristics. She explained, "A child
who's willing to always try their best and use different techniques to solve the

problem, whether it's using fingers or counters, or drawing the problem out to solve it" demonstrates mathematical understanding. She continued, "They're willing to persevere and try to solve it the best that they can."

When asked how she anticipated that teaching in a STEAM school would influence her beliefs about mathematics teaching and learning and her enacted practices, Rebecca responded, "I think the STEAM setting really allows me, personally, to tie math in all different areas…whereas a lot of other times I feel like with the math you have to stick with the pacing guide." She added, "I just feel like there's a lot more flexibility with STEAM."

MECS—STEAM survey responses.

In general, Rebecca's survey responses on the MECS--STEAM *Beliefs About Mathematics* sub-construct indicate that she holds beliefs about mathematics that are considered productive in light of reform efforts. However, just as in the pre-STEAM survey, she indicated that she "somewhat disagrees" that "mathematics involves making generalizations." There were no notable changes between her MECS—preSTEAM ratings and her MECS—STEAM ratings. Table 4.8 displays Rebecca's MECS--STEAM *Beliefs About Mathematics* sub-construct responses.

Table 4.8 *Rebecca's MECS--STEAM Beliefs About Mathematics sub-construct responses*

Item	MECS--STEAM
There is typically one way to solve a mathematics problem.	6
Doing mathematics involves analyzing multiple strategies for solving problems.	4
Mastering facts and developing skills for carrying out calculations is essential to knowing mathematics.	6
Mathematics is an attempt to know more about the world around us.	5
Mathematics involves making generalizations.	3
Mathematics is rarely used in society.	6
Mathematics involves constructing an argument.	4
Knowing mathematics is mostly about performing calculations.	5
Mathematics is essential to everyday life.	6

Description of Rebecca's final observation and accompanying RTOP scores.

Rebecca's final observation began in much the same way as the initial observation. She read a book aloud to the whole group and then provided explicit directions for each center. In Center 1, "Solo Cups," the students were instructed to build towers with the 100 Solo Cups. In Center 2, the students worked with the teaching assistant to make a "100th Days Snack." Students were instructed to count out ten of each of the ten snacks to make their bags. In Center 3, the students were instructed to work the "100th Day Puzzle." Rebecca held up an example of the puzzle and explained to the class, "Your picture will look just like this." In Center 4, the students worked with Rebecca to complete a "Mystery Picture."

The following exchange illustrates the instruction that occurred in Rebecca's "Mystery Picture" center during each rotation. Rebecca instructed, "Color in the number one." Rebecca and the students both colored in the box with the number one. Rebecca encouraged, "Good job! Now, color in the number four. Color in the number five. Color in the number six. Color in the number eight." Rebecca continued to model exactly what she wanted the students to do by coloring in the boxes as the students mimicked her actions on their sheets. Rebecca said, "There's a hidden picture, you have to pay attention." She continued to call numbers and color in the corresponding boxes as the students did the same until the hidden picture was revealed. Rebecca asked, "What do you see on your paper, what did you color?" The students responded, "100!" The students rotated to new centers every twelve minutes. Rebecca's center followed the same format each time. The class ended at after the fourth rotation.

As described in the episode above, Rebecca's finial observation lesson revealed transmission-oriented teaching practices that were very similar to those observed in her initial observation lesson. Students were not given the opportunity to explore the tasks using their own reasoning. Instead, Rebecca dominated the majority of the conversations as she modeled the exact procedure that the students were to follow. The focus of the lesson was on the final product. Additionally, Rebecca posed questions that served to keep the students listening and the students responded to the teacher with short, predictable answers. There were no opportunities for student-to-student construction of ideas observed in

this lesson. The use of mathematical representations was also notably absent in the lesson.

The RTOP scores recorded for the final observation lesson indicate that Rebecca did not enact reform-oriented teaching practices in the lesson. Table 4.9 provides Rebecca's final RTOP scores.

Table 4.9 *Rebecca's final RTOP scores*

Component	Post-RTOP
Lesson Design & Implementation	2
Content—Propositional Knowledge	5
Content—Procedural Knowledge	0
Classroom Culture—Communicative Interactions	3
Classroom Culture—Student/Teacher Relationships	4
TOTAL	14

Description of Rebecca's final interview responses.

The beliefs that Rebecca expressed about what constitutes "good" mathematics teaching remained consistent throughout the study. In the post interview, Rebecca explained, "I think someone who makes a good math teacher is somebody who can use a lot of different methods to teach the same concept…hands-on, visual, whatever meets the needs of their kids." She also described centers and rotations as reflecting "good" teaching.

She explained:

I would expect the teacher to be working with small groups and the rest of the kids in some type of center or small group setting working

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independently on skills that they have already gotten a foundation by working with the teacher.

This belief was consistent with the practices that were observed in the initial and final observations.

Rebecca's belief that a student's ability to complete a task independently constitutes mathematical proficiency and understanding also remained consistent. In the post-interview she explained, "Someone that's proficient in math would be someone who can independently show me that they understand the standards that were taught." Similarly, she maintained that a student with mathematical understanding is "somebody who is open minded and willing to try different ways to solve a problem…who understands that there's more than possibly one way to get an answer or there can be more than one answer."

In reflecting on the influence that teaching in a STEAM school has had on her beliefs about mathematics teaching and learning she stated, "Now I feel like my eyes have been really opened and I try to pull in STEAM throughout the entire day…I definitely think I am more willing to integrate math into other areas."

Stephanie

Stephanie, who currently teachers first grade, has four years of teaching experience. She has experience teaching mathematics in pre-kindergarten and first grade. She is certified in Early Childhood and Elementary Education and is currently pursuing her master's degree in Administration. This is her first year teaching in a STEAM school.

MECS—preSTEAM survey responses.

In general, Stephanie's survey responses on the MECS--preSTEAM *Beliefs About Mathematics* sub-construct indicate that she holds some beliefs about mathematics that are considered productive in light of reform efforts. However, she did "disagree" with the statement, "Mathematics involves making generalizations." Aditionally, she "somewhat disagreed" that "mathematics involves constructing an argument." Table 4.10 displays Rebecca's MECS--preSTEAM *Beliefs About Mathematics* sub-construct responses.

Table 4.10 *Stephanie's MECS--preSTEAM Beliefs About Mathematics sub-construct responses*

Item	MECS--preSTEAM
There is typically one way to solve a mathematics problem.	5
Doing mathematics involves analyzing multiple strategies for solving problems.	5
Mastering facts and developing skills for carrying out calculations is essential to knowing mathematics.	5
Mathematics is an attempt to know more about the world around us.	5
Mathematics involves making generalizations.	2
Mathematics is rarely used in society.	6
Mathematics involves constructing an argument.	3
Knowing mathematics is mostly about performing calculations.	4
Mathematics is essential to everyday life.	6

Description of Stephanie's initial observation and accompanying RTOP scores.

Stephanie began the initial observation lesson by posting a problem on the board. The problem read, "Make the number 35 using the blocks below." Stephanie explicitly directed the students to use base ten drawings (tens and

ones) to represent the number on their individual dry erase boards. The students worked independently to represent the number as the teacher circulated the class. Stephanie then called a student to the board to show how he solved the problem. The student used three tens and five ones to represent the number 35. Stephanie asked, "How may tens did he say?" The students responded, "Three." Stephanie then asked, "How many ones?" The students responded, "Five." Stephanie then posed the following problem: "Make the number 20 using the blocks below." She asked, "How many ones does the number 20 have?" Before the students had an opportunity to respond, she explained, "There are zero ones in the ones place."

The following scenario illustrates how Stephanie continued, throughout the lesson, to provide explicit directions for the procedures that the students were expected to follow. Stephanie instructed the students to get their math journals and a pencil and return to the carpet.

She instructed:

Open to the next empty page. Put the title "Groups of Ten" at the top.

Take a line and draw it down the middle and two lines across so you have

six rectangles. Put a number in the top corner of each one.

The students had brought in items in Ziploc bags such as pennies, pasta, and pom-poms. Stephanie placed the bags around the room and instructed the students to "count the items and put them in groups of ten." She demonstrated this process with the bag of pennies. She said, "I had four groups of ten so what's my number?" She continued, "I want to write my number and use a base

ten number to draw it." She then demonstrated exactly how the students were to record their work in their journals. Stephanie then instructed the students to work with partners to complete the assignment. The students worked together to count by tens and ones and wrote and represented the number with a drawing in their journals. As the students were working, Stephanie assumed the role of "helper" for students who were not following the prescribed directions. She helped one student count the bag of cubes and demonstrated for the student how to draw a "quick hundred," a "quick ten," and circles to represent the ones. After about ten minutes, Stephanie told the students to finish counting the bag that they were on and clean up. As the class came back together on the carpet, she asked, "Who can tell me something that they liked about doing this? One student responded, "I liked that you could draw the drawings of the number." Another student replied, "I liked that you could count by tens and not by ones." Stephanie probed, "Why is that important?" The student explained, "Because if you count by ones it would take you two days and if you count by tens it would be quicker." Stephanie paraphrased, "It's easier to count by tens than twos or ones." She then asked, "What was something you found difficult?" One student said, "Doing the beads because I couldn't answer it. There were over 100 beads." Another student added, "There were 1006 noodles!" Stephanie quickly replied, "There were not 1006!"

Stephanie's initial observation revealed transmission-oriented teaching practices. Students were not given opportunities to explore problems using their own mathematical reasoning and problem solving skills. Instead, Stephanie

provided explicit directions for how she expected the students to represent numbers and count collections of items. She specified the representations (i.e. base ten drawings) and solution strategies (i.e. counting by tens and ones) that the students were expected to use. Additionally, she dominated much of the conversation and assumed the role of "helper" when students were not following the prescribed directions.

The RTOP scores recorded for the initial observation lesson indicate that Stephanie did not enact reform-oriented teaching practices in the lesson. Table 4.11 provides Stephanie's initial RTOP scores.

Table 4.11 *Stephanie's initial RTOP scores*

Component	Pre-RTOP
Lesson Design & Implementation	3
Content—Propositional Knowledge	16
Content—Procedural Knowledge	8
Classroom Culture—Communicative Interactions	6
Classroom Culture—Student/Teacher Relationships	6
TOTAL	39

Description of Stephanie's initial interview responses.

In the initial interview, Stephanie expressed the belief that a "good" mathematics teacher "is willing to teach different strategies." She also expressed the belief that mathematics teachers should employ the use of manipulatives in helping students develop mathematical understanding. She explained, "My

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experience is whenever they have hands-on manipulatives…they can relate the lesson to something else so that it makes it more meaningful."

Stephanie described the role of the teacher in the mathematics classroom as one who models, helps, and questions students.

She described the teacher's role stating:

At the beginning of the lesson, I think the teacher is doing more modeling, but once the students understand the concept then the teacher is watching while the students are working independently, manipulating, and then the teacher kind of helps them once she sees them making a mistake or she's asking open-ended questions to see how they got the answer.

When discussing what constitutes mathematical understanding and proficiency, Stephane expressed the beliefs that mathematical understanding and proficiency involves using and explaining different strategies when solving problems.

She explained:

I think a good math student would probably be willing to get different strategies, like, there's not just one way to learn math and so be willing to learn different things…I think the most important thing in first grade would be for them to solve word problems and be able to think through their answers and how they would solve it. Listening to a problem and knowing

which operation to use and really be understanding the meaning of why they're solving the problem.

When asked how she thought teaching in a STEAM school would influence her beliefs about mathematics teaching and learning she expressed doubts that the setting would influence her beliefs and practices.

She explained:

Um, I don't know that it will really affect it. I think I usually teach a variety of strategies and it kind of depends on the students on what kind of strategy they pick up on. I don't know that the strategies are as much based on STEAM as, like, by the individual students and, like, what clicks for them. Because whenever it's primary math and it's pretty cut and dry I don't know that, um, I guess that the STEAM would influence the strategies as much.

MECS—STEAM survey responses.

In general, Stephane's survey responses on the MECS--STEAM *Beliefs About Mathematics* sub-construct indicate that she holds beliefs about mathematics that are considered productive in light of reform efforts. However, she continued to express doubts that "mathematics involves making generalizations." She did demonstrated growth on the "mathematics involves constructing an argument" item. In the pre-STEAM survey she "disagreed" with this statement and in the STEAM survey she "somewhat agreed" with the

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statement. Table 4.12 displays Stephanie's MECS--STEAM *Beliefs About*

Mathematics sub-construct responses.

Table 4.12 *Stephanie's MECS--STEAM Beliefs About Mathematics sub-construct responses*

Item	MECS--STEAM
There is typically one way to solve a mathematics problem.	5
Doing mathematics involves analyzing multiple strategies for solving problems.	5
Mastering facts and developing skills for carrying out calculations is essential to knowing mathematics.	5
Mathematics is an attempt to know more about the world around us.	5
Mathematics involves making generalizations.	3
Mathematics is rarely used in society.	6
Mathematics involves constructing an argument.	4
Knowing mathematics is mostly about performing calculations.	4
Mathematics is essential to everyday life.	6

Description of Stephanie's final observation and accompanying

RTOP scores.

The teacher-centered practices observed in Stephanie's final observation

lesson were consistent with the practices witnessed in the initial observation

lesson. Stephanie began the lesson by explicitly demonstrating how to use the

number line to "count on" when adding. As she modeled, she said, "Start with the

biggest number and count up." The students mimicked the procedure on their

individual dry erase boards. Stephanie then presented the students with several

problems that required them to use the number line to "count on." The problems

were presented individually, the students were given a few minutes to work the

problems independently on their individual dry erase boards, and select students

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were invited to work the problems in front of the class. Each time a student shared with the class, Stephanie facilitated a predictable series of questions and answers. She instructed each student to "show us how you got the answer with the number line." She then asked, "How many jumps?" The students responded in unison. Finally, she asked the class, "What's the sum?" The students, once again, responded in unison.

Stephanie presented the "new" strategy of counting on by one, two, or three in the same way. She instructed the students to circle the bigger number, put that number in their head, and count up one, two, or three. She demonstrated the procedure for the students as they mimicked the procedure on their dry erase boards. Once again, several problems were displayed for the students to use in applying the strategy and select students were invited to work the problems in front of the class. As each student worked the problem, Stephanie asked a predictable series of questions. She began, "What do I put in my head?" Then asked, "How many times do I count up?"

Finally, she said, "I want you to practice giving your turn and talk partner a problem that has something plus one, something plus two, and something plus three." The students turned "knee-to-knee" and began to share their problems. Stephanie monitored the conversations and interjected, once again assuming the role of "helper," when students were making errors.

These episodes from the finial observation lesson indicate that Stephanie continued to enact practices that were not reform-oriented. Namely, she provided explicit instructions for how students were expected to represent and solve

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problems (e.g. "counting on" using a number line, "counting on by one, two, or three"). She also dominated the conversations and asked predictable questions that were focused on correctness and students provided short, answer-focused responses. Finally, Stephanie continued to assume the role of "helper" when her students made errors.

The RTOP scores recorded for the final observation lesson indicate that Stephanie did not enact reform-oriented teaching practices in the lesson. Table 4.13 provides Stephanie's final RTOP scores.

Table 4.13 Stephanie's final RTOP scores

Component	Post-RTOP
Lesson Design & Implementation	3
Content—Propositional Knowledge	8
Content—Procedural Knowledge	4
Classroom Culture—Communicative Interactions	5
Classroom Culture—Student/Teacher Relationships	6
TOTAL	26

Description of Stephanie's final interview responses.

Stephanie's beliefs that a "good" mathematics teacher uses a variety of teaching strategies, including hands-on experiences with manipulatives, remained consistent throughout the study.

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In the post-interview, she explained:

I think a good mathematics teacher would be teaching her students with a lot of different strategies. With different manipulatives and letting them have opportunities to explore in their learning and how they are thinking through the work. Allowing them to work together and independently and giving them different ways of learning…whether it's whole group, small group, individual work or whatever.

She explained that in an ideal mathematics classroom "some students may be working on mastering fluency, some may be working with the teacher on word problems, some may be reviewing old concepts…the conversation is on topic and the students are fully engaged in what they're working on."

Stephanie's beliefs about the role of the teacher in the mathematics classroom also remained consistent. In the final interview, she maintained that the role of the teacher is one of monitor, helper, and questioner.

She described the teacher's role in the following way:

Most of the time I'd say the teacher would be working on a small group to kind of intervene, but sometimes you could see the teacher not as much like the focal point, but making sure that the class is managed and facilitating the learning by giving the kids what they need to do to solve the problems…Just making sure that the kids, you know, kind of wondering around making sure that their conversations are on task and clearing up any misconceptions she sees while they're working.

Stephanie's description of what constitutes mathematical proficiency in the final interview focused more on students' perseverance than her description in the initial interview. She explained, "I think a good math student is someone who's willing to make mistakes and willing to see how to solve the problem…If they do make the mistake and try it again and not feel defeated if they get the wrong answer." She also focused more on students' ability to connect mathematics to the real world. She insisted that mathematical proficiency means "being able to use math problems in real world situations...they're just using it during their everyday conversations…It's not on a test. Whenever they're just using it during their everyday conversations."

While Stephanie revealed doubts in the pre-interview about the influence that teaching in a STEAM setting would have on her mathematics teaching, her responses to similar questions in the final interview revealed that the STEAM setting strengthened her belief that real world problems should play a major role in mathematics teaching and learning.

She reflected:

I think math is so important whenever they're using it to solve real world problems. I think that's the whole idea behind STEAM. That they are taking their learning and trying to solve something larger and then they notice their impact on it. I think that's what's great about the STEAM school …We have the opportunity to have guest speakers that go along with our project and then it gave the kids a whole new appreciation for why we're learning math and why it's so important in how they're going to use it

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when they're adults and it makes it a little more relevant. I think it makes kids more passionate when they understand the reason they have to know something is because they're going to use it later on. It's not just temporary knowledge…After we had that one speaker, I had a student that I was struggling to reach an interest with and he really thought it would be great to be a coastal engineer. He wrote in his journal about how he is going to work so hard in math because that's what he wants to be. I think it gave him a little more willpower to work hard and study and learn those facts just so that he could become what he wanted to be. That's kind of powerful.

Stephanie's description of the influence the STEAM setting has had on her and her students demonstrates an awareness of the important role that situating mathematics in the real world plays in developing mathematical understanding.

Tiffany

Tiffany, who currently teaches second grade, has over thirty years of teaching experience. While she has taught mathematics in all elementary grades, this is her first experience teaching in a STEAM school. She has a master's degree and is certified in Early Childhood and Elementary Education.

MECS—preSTEAM survey responses.

Tiffany's survey responses on the MECS--preSTEAM *Beliefs About Mathematics* sub-construct indicate that she holds beliefs about mathematics that are considered productive in light of reform efforts. Table 4.14 displays

Tiffany's MECS--preSTEAM *Beliefs About Mathematics* sub-construct
responses.

Table 4.14 *Tiffany's MECS--preSTEAM Beliefs About Mathematics sub-construct responses*

Item	MECS--preSTEAM
There is typically one way to solve a mathematics problem.	6
Doing mathematics involves analyzing multiple strategies for solving problems.	6
Mastering facts and developing skills for carrying out calculations is essential to knowing mathematics.	5
Mathematics is an attempt to know more about the world around us.	5
Mathematics involves making generalizations.	5
Mathematics is rarely used in society.	6
Mathematics involves constructing an argument.	6
Knowing mathematics is mostly about performing calculations.	6
Mathematics is essential to everyday life.	6

Description of Tiffany's initial observation and accompanying RTOP scores.

Tiffany initiated the initial observation lesson by posing a problem solving task to the students. Prior to reading the problem to the students, she said, "Remember to take notes." She then read the following problem aloud to the class: "Luke bought twenty-five cookies. He gave his sweetheart eight of the cookies. How many cookies does Luke have now?" She reminded the students, "When you're taking notes it's not necessary to write down every single word." The students were given the opportunity to use their reasoning strategies to make sense of and solve the problem. She also made sure that the students understood that they were expected to explain and discuss how they thought

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about and solved the task. She instructed, "Be prepared to share your information. We will take a look at a couple different ways people solved it." Tiffany walked around monitoring the students as they explored the task. She asked individual students to share their thinking. She came across one student who only had the answer written on his board. Tiffany encouraged the student to make his mathematical thinking visible explaining, "You have to have more than that. A stranger should be able to look at your work and be able to figure out what you did." As she monitored, she selected a few students to share with the class. She transitioned the students to the carpet, called one student to the board, and instructed him to explain how he solved the problem. The student recorded the correct answer (17) on the board. Tiffany demonstrated the value that she places on the problem solving process by asking, "I'm just wondering where you got this 17 from? The answer is correct, but I have to know how you got it." The student explained, "I took this number and minused it with this number." Tiffany said, "We'll come back to this." She then a called another student to the board to explain her strategy. She instructed the student to write her solution strategy directly under the first student's work. The student explained, "My mom taught me how to do this." She then demonstrated the algorithm. Tiffany, with the input of the students, connected the regrouping illustrated in the first strategy to the algorithm that was presented by the second student. Finally, Tiffany selected a student to share the work that was recorded on his dry erase board. The student explained, "I used circles to represent the cookies and I put x's on the ones that he gave to his sweetheart." Tiffany then

facilitated a discussion connecting the different strategies. Figure 4.2 illustrates

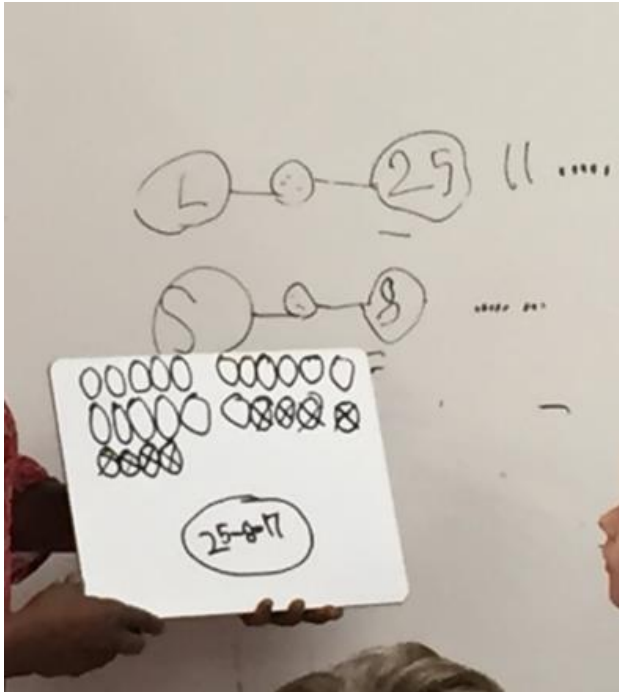the visuals that Tiffany used to facilitate this discussion.

Figure 4.2 *Sweetheart task strategies*

  This excerpt from the initial observation illustrates Tiffany's reform-

oriented teaching practices. Instead of explicitly "teaching" her students how to

solve the problem, she provided them with the opportunity to explore the task

using their own reasoning and problem solving strategies. Additionally, she

assumed the role of facilitator of learning by prompting and posing questions that

helped the students make the mathematics visible and deepen their

mathematical understanding. She also placed value on the process, not just the

correct answer, and insisted that her students were able to explain and justify

their thinking. Finally, she facilitated a conversation to help the students see how

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the different representations and solution strategies were alike and how they were different.

Tiffany's initial observation RTOP scores indicate that she enacted reform-oriented teaching practices in her lesson. Table 4.15 provides Tiffany's initial RTOP scores.

Table 4.15 *Tiffany's initial RTOP scores*

Component	Pre-RTOP
Lesson Design & Implementation	17
Content—Propositional Knowledge	14
Content—Procedural Knowledge	11
Classroom Culture—Communicative Interactions	14
Classroom Culture—Student/Teacher Relationships	17
TOTAL	73

Description of Tiffany's initial interview responses.

In the initial interview, Tiffany expressed the belief that a "good" mathematics teacher utilizes hands-on experiences and manipulatives to cultivate students' mathematical understanding. She explained, "A [good mathematics teacher] allows the children to explore with manipulatives…They have to have a grasp on the really deep things…the manipulatives can get them there." Additionally, she advocated for the important role that mathematical discourse plays in quality mathematics instruction. She insisted, "In a classroom there should be many opportunities for the children to voice their learning." She continued, "The children learn how to listen, how to ask questions about whatever it is that they are explaining. I think it's important for that to happen."

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When asked to express her beliefs about what constitutes mathematical understanding and proficiency, Tiffany prioritized students' abilities to take risks and persevere. She described mathematical proficiency as "a child that's willing to take risks and persevere."

In the initial interview, Tiffany explained that she did not believe that teaching in a STEAM school would influence her beliefs about mathematics teaching and learning. Instead, she explained, the setting would provide more flexibility and confirmation of the quality of her existing practices.

She explained:

I think there are a lot of things that are already in place with me because of where I am with my teaching, my experience. So, what I'm finding true is some of the practices that we're doing with the STEAM, they're already a part of it. So, it's like confirming that these are good practices.

She described that the setting enables her to "not feel confined or pressured and allows the children to be more confident and explore more things by being in a STEAM school."

MECS—STEAM survey responses.

Tiffany's survey responses on the MECS--STEAM *Beliefs About Mathematics* sub-construct indicate that she holds beliefs about mathematics that are considered productive in light of reform efforts. There were no notable changes between her MECS—preSTEAM ratings and her MECS—STEAM

ratings. Table 4.16 displays Tiffany's MECS--STEAM *Beliefs About Mathematics* sub-construct responses.

Table 4.16 *Tiffany's MECS--STEAM Beliefs About Mathematics sub-construct responses*

Item	MECS--STEAM
There is typically one way to solve a mathematics problem.	6
Doing mathematics involves analyzing multiple strategies for solving problems.	6
Mastering facts and developing skills for carrying out calculations is essential to knowing mathematics.	6
Mathematics is an attempt to know more about the world around us.	6
Mathematics involves making generalizations.	5
Mathematics is rarely used in society.	6
Mathematics involves constructing an argument.	6
Knowing mathematics is mostly about performing calculations.	5
Mathematics is essential to everyday life.	6

Description of Tiffany's final observation and accompanying RTOP scores.

Just as in the initial observation, Tiffany enacted reform-oriented teaching practices in her post observation lesson. She began the lesson by holding up a 3-D card that one of the students had given to her. She asked, "If I wanted to measure the length, what would be a good measuring tool or unit for me to use?" The students responded, "Centimeters." Tiffany asked, "Why do you think centimeters?" One students explained, "Because the card is really small." Another student added, "You could also use inches." Tiffany responded, "I think those are two good choices."

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Tiffany transitioned, "You're going to be collaborating, eye-to-eye." She explained, "In your groups you have to stay in your area, you can turn your body and look at different things in the classroom and figure out an item that would measure one foot." The students had thirty seconds to identify something in the room that would measure one foot. Students immediately began working and discussing in their groups. Each group was then given the opportunity to share and measure the item that they selected. Tiffany asked questions such as, "How many inches?" and "How are you measuring it?" After posing the questions, Tiffany waited patiently for the student(s) to articulate and justify their strategies.

Tiffany then instructed the students to form a circle on the carpet. She held up a meter stick and a yardstick. She then facilitated a conversation about how the meter stick and yardstick are a like and how they are different. The students noticed that the meter stick is made up of centimeters and the yardstick is made up of inches. Tiffany asked, "How many inches are on the yardstick? How many feet?" Tiffany listened as the students discussed their strategies for figuring out how many feet and how many inches. One student said, "There are 36 inches because ten plus ten plus ten plus two plus two plus two equals thirty-six inches." Another student demonstrated how three 12-inch/1foot rulers make up the same length as a yardstick. Tiffany explained, "You're going to be doing some measuring yourself." She directed the students to turn to a page in their textbooks and measure the objects that were indicated in the textbook. As the groups worked, Tiffany monitored and probed students' thinking saying, "Let me see, measure it again."

After a few minutes of observation, Tiffany pulled the students back to the carpet. It was evident that she had noticed her students making some common measurement errors. She said, "I saw some measuring strategies I want you to be aware of." She explained, "We're going to observe, not judge, and then we are going to talk about it." Each student then demonstrated her measurement strategy. Once the demonstrations were complete, Tiffany said, "Sit like morning meeting so we can talk about our observations." She continued, "Tell me what you noticed. Would you think that was an accurate way to measure?" She then allowed the students to share their observations and offer suggestions for how the measuring would be more accurate. Tiffany summarized the students' suggestions stating, "Remember, we talked about the importance of accuracy with measurement around the world. Make sure the ruler is at the very end. You have to mark it."

Tiffany then initiated a discussion about why it is important to measure precisely in the real world. She asked, "How could I use this in the real world? What's something that could cause major problems? Why would I be measuring this rug in the real world?" She then gave the students an opportunity to discuss the reasons why someone would have to measure the rug. Next, she encouraged the students to "Tell me something in your real life." One student said, "Medicine!" Tiffany probed, "Why?" Tiffany then facilitated a discussion about why it is important to measure medicine carefully.

The final observation lesson ended as Tiffany initiated a conversation about collaboration. She said, "I want to talk about your collaboration some.

There are a lot of good things that you are doing. I think Tuesday's table works really well together. Wednesday's group is very efficient. If you have any tips just raise your hand." She then allowed the students to share "tips" for collaborating within their groups.

Tiffany ended the lesson by saying:

Working together, working in a group takes patience and you have to listen. Some of the really awesome things I've learned I didn't learn them by talking, I learn more when I'm listening. Listening is a good skill that you can use when you are working with teams.

The excerpts described in the preceding paragraphs exemplify the reform-oriented teaching practices that were observed in Tiffany's post observation lesson. She used questioning to help elicit and deepen students' understanding. She also utilized mathematical discourse as a tool for responding to student errors and establishing an environment that cultivated student-to-student construction of ideas. An area of growth that should be noted is the importance that she placed on situating the mathematics in authentic, real world situations.

Her RTOP score scores indicate that Tiffany enacted reform-oriented teaching practices in her final observation lesson. Table 4.17 provides Tiffany's final RTOP scores.

Table 4.17 *Tiffany's final RTOP scores*

Component	Post-RTOP
Lesson Design & Implementation	18
Content—Propositional Knowledge	19
Content—Procedural Knowledge	18
Classroom Culture—Communicative Interactions	19
Classroom Culture—Student/Teacher Relationships	16
TOTAL	90

Description of Tiffany's final interview responses.

In the final interview, Tiffany maintained her beliefs that quality mathematics instruction consists of hands-on learning opportunities in which students have access to manipulatives. She also maintained her belief in the role that mathematical discourse plays in quality mathematics instruction. She insisted, "Working with manipulatives, being able to talk about their learning, and models are very important." In the final interview, Tiffany also advocated for the use of authentic, real world problems in mathematics teaching and learning. She said that providing real world experiences is important because "for young kids, especially when you're just figuring things out for no reason, teaching them the algorithm and they don't get how that works in the real world."

Tiffany said that the teacher's role in a mathematics classroom is to think about the misconceptions that students may have and "really put a lot of thought and planning into how you're going to teach different skills." She continued, "I really put a huge responsibility on them for listening and being receptive to other people's ideas because they may can find an easier way to do things."

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In the final interview, Tiffany maintained her position that mathematically proficient students should be willing to take risks and preserve in solving problems. She also emphasized the importance of students being able to connect the mathematics that they are learning to the real world. She explained, "I think they realize as we talk about mathematics how to use math in the everyday world, that it's not isolated."

Tiffany explained that teaching in a STEAM school has influenced her mathematics teaching by making her more aware of integrating and the importance of situating learning in authentic, real world situations.

She explained:

I think thinking and planning more strategically that I am more aware…I'm more aware of integrating everything that we're doing…I think it provides more of an in depth process for planning of trying to make everything connect and so I think that would be growth.

She added, "I think as far as real world situations that the STEAM explorations that we do lend themselves to it…I think it probably makes things more real and logical for the children."

Findings

The analysis of the data collected in this study revealed four major findings. Namely, this study revealed: (1) Teachers in a STEAM school expressed similar and consistent beliefs about the teaching and learning of mathematics that are considered productive in light of reform efforts. (2)

Teachers in a STEAM school enacted divergent practices. (3) Teaching in a STEAM school strengthened teachers' beliefs about the importance of integration and connecting mathematics to authentic, real world situations. (4) Teaching in a STEAM school influenced teachers' enacted practices in relation to situating mathematics in authentic, real world situations. Each finding is described below in relation to the corresponding research question.

Research Question 1

This study investigated the following research question: What are the beliefs about the teaching and learning of mathematics held by elementary mathematics teachers situated in a STEAM school? One major finding emerged in relation to this question: Teachers in a STEAM school expressed similar and consistent beliefs about the teaching and learning of mathematics that are considered productive in light of reform efforts.

Finding one: Similar and consistent beliefs.

Teachers in a STEAM school expressed similar and consistent beliefs about the teaching and learning of mathematics that are considered productive in light of reform efforts. These beliefs emerged, through an analysis of the qualitative data, in the areas of mathematics teaching and learning and what constitutes mathematical understanding and proficiency.

The responses of the participants on the MECS *Beliefs About Mathematics* sub-construct in the MECS—pre-STEAM and MECS—STEAM supported the finding that the teachers situated in a STEAM school hold similar

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and consistent beliefs about mathematics teaching and learning. Higher ratings indicate productive beliefs toward reform-oriented mathematics. Consistent with the analysis of the qualitative data, an analysis of each item revealed that some beliefs are held more consistently than other beliefs. Specifically, each of the participants "strongly agreed" that "mathematics is an attempt to know more about the world around us" and that "mathematics is essential to everyday life."

Theme 1.a.: Beliefs about quality mathematics teaching and learning.

Participants in this study consistently expressed beliefs that the standards, multiple instructional strategies, including hands-on and differentiation, and a focus on multiple solution strategies are essential elements of quality mathematics teaching and learning. The teachers characterized "good teaching" as knowing the standards and understanding what students are expected to know. Lillian's description in the initial interview of what makes a "good" mathematics teacher illustrates the beliefs expressed by all of the participants. She explained, "It starts with knowing the standards…looking at the standard and thinking about from the standards what it is that my kids need to know?" The teachers also consistently expressed the belief that employing a variety of instructional strategies and differentiating mathematics instruction is an essential component of quality mathematics teaching.

In her initial interview, Rebecca explained:

I think what makes a good math teacher is someone who is willing to differentiate instruction to meet the needs of all kids and, also, use all

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different types of techniques to teach math skills…hands-on, audio, visual, whatever kids need to allow them to succeed.

Stephanie expressed a similar sentiment in her final interview:

I think a good mathematics teacher would be teaching their students with a lot of different strategies. With different manipulatives and letting them have opportunities to explore in their learning and how they are thinking through the work. Allowing them to work together and independently and giving them different ways of learning…whether it's whole group, small group, individual work or whatever.

The beliefs that mathematic learning should be hands-on and employ the use of manipulatives was consistent among all of the participants. Tiffany explained in the initial interview, ""They have to have a grasp on, you know, like the really deep things…the manipulatives can get them there." Finally, the teachers expressed the belief that teachers should cultivate different solution strategies. Lillian explained in the post interview that a good mathematics teacher is "someone who believes that there's lots of ways to solve the problem." Stephanie simply stated in the initial interview that a good mathematics teacher "is willing to teach different strategies."

Theme 1.b.: Beliefs about what constitutes mathematical understanding and proficiency.

The participants in this study expressed common beliefs about what constitutes mathematical understanding and proficiency. The participants, as a

whole, believe that mathematical proficiency consists of a balance of procedural fluency and conceptual understanding. They also consistently reported using students' success with the standards as a measure for mathematical proficiency. Additionally, the participants in this study consistently expressed the belief that students demonstrate mathematical understanding by solving problems and representing numbers in multiple ways. The teachers also collectively regard risk taking and perseverance as an aspect of mathematical understanding and proficiency.

There was an agreement among the participants that mathematical understanding and proficiency consists of a blend of procedural fluency and conceptual understanding.

In the initial interview, Lillian described the importance of this blend in stating:

Proficiency would be kind of a combination of conceptual understanding and the procedural fluency. If they only understood the concept, but it took them, they had to do a strategy every single time, for every single thing, it would take forever and they wouldn't be efficient. But if they only just had certain things memorized and they didn't really know why they wouldn't really ever be able to apply that same understanding to other situations, so it wouldn't be totally proficient that way either. So, I think it's a blend.

The participants also defined mathematical proficiency in terms of students' success with standards. In the final interview, Lillian defined

mathematical proficiency as "being proficient with the standards." Rebecca echoed that view in the initial interview stating, "I'd say it's pretty much when you look at the standards across where they're at."

Another component of mathematical understanding, the participants agreed, is the ability to represent and solve mathematics problems in different ways. Stephanie explained in the initial interview, "I think a good math student would probably be willing to get different strategies, like, there's not just one way to learn math and so be willing to learn different things." A good mathematics student, Rebecca agreed in the final interview, is "somebody who is open minded and willing to try different ways to solve a problem."

The teachers agreed that affective factors such as risk taking and perseverance are essential in developing mathematical understanding. The teachers expressed beliefs that a child's willingness to "take risks" and "be wrong" play a role in developing mathematical understanding. Stephanie explained in the final interview that a good mathematics student is "willing to be wrong" and "willing to try and try again." Perseverance was also a student characteristic that was valued by all of the study participants. In the initial interview, Rebecca explained that a good mathematics student is "willing to persevere and try to solve it the best that they can."

Research Question 2

This study also investigated the following research question: How does teaching in a STEAM school influence the enacted practices and beliefs of

teachers about teaching and learning mathematics? Three findings emerged in relating to this question: (1) Teachers in a STEAM school enacted divergent practices (finding two). (2) Teaching in a STEAM school strengthens teachers' beliefs about the importance of integration and connecting mathematics to the real world (finding three). (3) Teaching in a STEAM school influences teachers' enacted practices in relation to situating mathematics in the real world (finding four).

Finding two: Divergent practices.

The analysis of the data collected in this study revealed the finding that teachers in a STEAM school enacted divergent practices. Lillian and Tiffany enacted reform-oriented teaching practices that were in alignment with their beliefs while Rebecca and Stephanie enacted traditional/transmission-oriented practices that lacked alignment with their beliefs. Specifically, evidence demonstrates that Lillian and Tiffany's enacted practices were reflective of the *Eight Mathematics Teaching Practices* (NCTM, 2014) that were used to frame reform-oriented mathematics teaching in this study. On the contrary, these practices were not evidenced in Rebecca and Stephanie's enacted practices. The *Eight Mathematics Teaching Practices* include:

1. Establish mathematical goals to focus learning.

2. Implement tasks that promote reasoning and problem solving.

3. Use and connect mathematical representations.

4. Facilitate meaningful mathematical discourse.

5. Pose purposeful questions.

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6. Build procedural fluency from conceptual understanding.

7. Support productive struggle in learning mathematics.

8. Elicit and use evidence of student thinking.

In the following discussion, I will cite the practices by their corresponding number. For example, I will refer to the practice of *establishing mathematical goals to focus learning* as Practice #1.

There were clear differences in the types of tasks that each pair posed to their students as well as in the implementation of the tasks. The use of mathematical discourse was another area where divergent practices emerged. Finally, there were clear differences in both the expressed beliefs and enacted practices in relation to the roles of teachers and students. Table 4.18 illustrates the divergent practices that were observed.

Table 4.18 *Divergent practices*

Divergent Practices	Tiffany and Lillian (reform-oriented)	Rebecca and Stephanie (traditional/transmission-oriented)
Task Type	Authentic, real world Promoted reasoning and problem solving	Isolated, void of real world connections
Task Implementation	Provided opportunities for students to develop and deepen *their own* mathematical understanding Focus on understanding the problem and being able	Modeled explicit procedures for solving problems

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	to explain and justify solutions	
Nature of Mathematical Discourse	Conceptually-oriented Focused students' attention toward rich conceptions of situations, ideas, and relationships Reflected sociomathematical norms	"Computationally" oriented Focused on the problem to be solved, prioritized the answer Expectations for student explanations were shallow and incomplete
Treatment of Errors	Capitalized on student errors as opportunities to clarify and deepen mathematical understanding	Quickly corrected student errors with little to no explanations
Use of Mathematical Representations	Tools for developing mathematical understanding and facilitating student discourse	Focus was on the representation Teachers modeled explicitly how to "do" the strategy
Teacher's Role	Facilitator	Modeler/Helper
Students' Role	Responsible for developing their own mathematical understanding through problem solving and mathematical discourse	Follow directions, work independently

Theme 2.a.: Task selection and implementation.

There were stark differences in the types of tasks that each pair of

teachers posed to their students as well as in the implementation of the tasks.

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Lillian and Tiffany used tasks that promoted reasoning and problem solving as curricular resources for advancing student learning (Practice #2). These authentic, real world tasks provided students with opportunities to develop and deepen their own mathematical understanding, building procedural fluency from conceptual understanding (Practice #6). The focus in Lillian and Tiffany's classrooms was on understanding the problem and being able to explain and justify solutions. This is evidence of a conceptually-oriented stance toward teaching mathematics (Thompson, Thompson, & Boyd, 1994). Rebecca and Stephanie, on the other hand, utilized isolated problems that were void of any real world connections to model explicit procedures for solving problems evidencing a "calculational" orientation toward teaching mathematics teaching (Thompson, Thompson, & Boyd, 1994).

Lillian and Tiffany both used tasks that promoted reasoning and problem solving as curricular resources for advancing student learning (Practice #2). Lillian explained, "I think you have to create opportunities for your students to experience…to come to their own understanding." When presenting their students with a problem, both Lillian and Tiffany placed a focus on understanding the problem. Lillian encouraged her students to "picture in your head what is happening and how you might solve it." She explained to the students, "As you are reading you should be looking for clues and thinking, 'What is the problem even asking?'" Tiffany took a similar approach with her students instructing, "When you have a story problem you have to focus on 'What is the problem?'" Their focus on helping students develop a rich conception of the situation helped

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the students develop procedural fluency from conceptual understanding (Practice #6).

Lillian and Tiffany believe that it is important to engage their students in authentic, real world problems. Tiffany said, "I think for young kids especially when you're just figuring things out for no reason, teaching them the algorithm, and they maybe don't get how that works in the real world." She continued, "Students best learn mathematics when they're given real world situations that mean something to them." Lillian insisted, "If they can't apply it to a real situation then they probably don't even really understand what it means." The belief in the importance of using authentic, real world problems and connecting mathematics learning to the real world was evident in the enacted practices of both Lillian and Tiffany. Both teachers presented problems to the students that included the names of students in the class and/or situations that were authentic to the classroom audience. For example, Tiffany posed the following problem, "Luke bought 25 cookies. He gave his sweetheart 8 of the cookies. How many cookies does Luke have now?" Luke is the name of one of the students in her class. Lillian also included the names of students in the problems she presented to the class. She even connected one problem to composting. This situation was authentic for her students because they were in the process of collecting food scraps to compost. Lillian posed the following problem, "Mrs. Elizabeth's class put 7 apples in the compost bin. Mrs. Lillian's class put 8 more apples in the compost bin. How many apples are in the compost bin?" The teachers also placed an emphasis on how mathematics is related to the real world through their

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questioning and discussions. This is exemplified in the discussion that Tiffany's class had about when it is important to measure accurately. Tiffany asked, "How could I use this in the real world? What's something that could cause major problems?" "Why would I be measuring this rug in the real world?" She then gave the students an opportunity to discuss the reasons why someone would have to measure the rug. Next, she encouraged the students to "Tell me something in your real life." One student said, "Medicine!" Tiffany probed, "Why?" Tiffany then facilitated a discussion about why it is important to measure medicine carefully.

It is also important to note that the word problems presented in Lillian and Tiffany's classrooms reflect those identified by Carpenter et al.'s (1999) *Classification of Word Problems* (e.g. Separate-Result Unknown). Lillian and Tiffany both posed word problems to their students and encouraged students' intuitive use of strategies for solving the problems and focused on these strategies for reflection and discussion. Cognitively Guided Instruction (CGI), as employed by Lillian and Tiffany, supported the implementation of tasks that promote reasoning and problem solving (Practice #2), the use of mathematical representations (Practice #3), meaningful mathematical discourse (Practice #4), building procedural fluency from conceptual understanding (Practice #6), and the use of student thinking (Practice #8).

Rebecca and Stephanie both expressed the belief that problem solving should play a dominant role in mathematics teaching and learning.

Rebecca described the importance of providing opportunities for kindergarteners to experience problem solving:

Problem solving is huge in kindergarten and not just math. Of course, it ties in with math because it's very easy to give them a problem and have them solve it as far as numbers or, you know, measurement or shapes. Problem solving as a whole, kindergarten kids a lot of times don't want to solve problems because everything is done most of the time for them. So, just for an example tying in socially, "How can you solve this problem?" Like, I just feel like I am constantly asking my kids, "How can we solve this problem? So and so isn't sharing. How can you solve?" So, I just feel like building that skill of problem solving in kindergarten is huge because it ties in with everything. It ties in with the social skills they have to have. And then, again, with math, this morning we did a missing number sheet and they, some of them got it and some of them didn't get it and it was interesting to see who didn't get it. Um, because some kids you would think would get it, didn't and they just were confused because it had missing numbers and, so, instead of me saying, "No, no that's wrong, you need to do…" I said, "What can you use to help you solve, you know, complete this sheet?" And they would go to the "wall of numbers." So, I feel in kindergarten, you have to lead them to become problem solvers, but sometimes it's hard because it's really easy as a teacher to solve it for them because you get frustrated. But you have to let them, you know,

grow and become problem solvers because it helps them in every single aspect of their life.

Stephanie also emphasized the importance of problem solving in mathematics:

I think the most important thing in first grade would be for them to solve word problems and be able to think through their answers and how they would solve it. Listening to a problem and knowing which operation to use and really be understanding the meaning of why they're solving the problem not just, you know, knowing seven minus three is four, but know the process in which they take to get to that answer.

The enacted practices that were observed for both of these teachers did not include the types of problem solving opportunities that were described in their interviews. Rebecca presented the students with problems such as, "I'm thinking of a number that is bigger than two but smaller than four." She did not relate the problems to any type of real world situation. Similarly, Stephanie presented the students with problems such as "8 + 2 = __." She also did not relate the problems to any type of real world situation. Instead, she posed the isolated equations and explicitly modeled how to solve them by using a number line and counting on.

Theme 2.b.: Nature of mathematical discourse.

The divergence in enacted practices were the most evident in the nature of mathematical discourse that was exemplified by each pair. Lillian and Tiffany exhibited a conceptually-oriented stance toward mathematics teaching while

Rebecca and Stephanie exhibited a "computationally" oriented stance toward mathematics teaching (Thompson, Thompson, & Boyd, 1994). Specifically, Lillian and Tiffany focused "students' attention away from thoughtless application of procedures and toward a rich conception of situations, ideas, and relationships among ideas" (Thompson, Thompson, & Boyd, 1994, p. 46). Additionally, Lillian and Tiffany's expectations for student explanations reflected sociomathematical norms (Yackel & Cobb, 1996) that valued: (1) Explanations that consist of mathematical arguments, not simply descriptions of procedures or summaries of steps. (2) Capitalizing on errors as valuable opportunities for discussion, exploration, and reconceptualization. (3) Understanding the relationships among multiple strategies. (4) Collaborative work that involves individual accountability and consensus reached through mathematical argumentation. Students were expected to explain and justify their solutions and to use different representations to support those explanations. Additionally, Lillian and Tiffany capitalized on student errors as opportunities to clarify and deepen mathematical understanding. Discourse played a major role in both Lillian and Tiffany's mathematics classrooms. The prominent role that mathematical discourse played in the classrooms is a reflection of the value that both teachers place on verbalizing and discussing mathematical ideas. Lillian and Tiffany were intentional about setting the expectation for student talk with their students. Lillian reminded her students, "You're going to solve, share with your partner, and then we're going to talk about it." Tiffany instructed her students, "Be prepared to share your information. We will take a look at a couple different ways people

solved it." Both teachers also encouraged student-to-student sharing of ideas by employing strategies such as, "knee-to-knee, toe-to-toe." Lillian frequently encouraged her students to, "Turn to your partner and explain how you solved the problem." Tiffany insisted, "In a classroom there should be many opportunities for the children to voice their learning." This occurs, she explained, through asking questions such as, "How did you figure that out?" Lillian shared this sentiment stating, "There's value in talking." Lillian explained the benefits of mathematical discourse in stating, "I think it's helping them, like, firm up their understanding and it's helping me see what they know." Tiffany also described the benefits of student discourse, "I think definitely for different viewpoints to come into play and I think sometimes children are more responsive to their peers showing them a different way. They can put it in a language they understand, connect with it." She continued, "I think they realize as we talk about mathematics how to use math in the everyday world, that it's not isolated." Lillian suggested that student discourse is an essential component of mathematical proficiency.

She described evidence of mathematical understanding in the following way:

The ability to solve problems in diverse ways, justify those problems, listen to other people's justifications for theirs, and think about yours. Like, making connections to other ways to solve it. Not thinking that there's just one, like, one way. Um, basically, being able to solve problems and understand how and why.

Lillian and Tiffany both encouraged multiple mathematical representations (Practice #3) as tools for developing mathematical understanding (Practice #6) and facilitating student discourse (Practice #4). Tiffany explained, "The children being able to represent their work in different ways and also, included with that, that they can verbalize what they're thinking. I think if they can verbalize it then they really understand what they are doing." Lillian described how she thinks students learn mathematics best in stating, "I think through doing and through talking about it and through representing problems." Tiffany explained to her students that "a stranger should be able to look at your work and be able to figure out what you did." In response to a student who said, "I did it on my fingers." Lillian said, "Show me what you did on your fingers. How could you represent that using a drawing? I want you to practice drawing it so you can see what you are doing." In response to a student's explanation about making a ten and then adding five more, Lillian encouraged, "Use the ten-frame so everybody can see in their head what you're talking about."

Finally, both Lillian and Tiffany used student talk to capitalize on errors that occurred during problem solving tasks. Tiffany noticed two students who were leaving gaps and overlaps when completing a measurement task. She called all of the students to the carpet and said, "I have some measurement strategies I want you to be aware of." She explained, "We're going to observe, not judge, and then we are going to talk about it." Each student then demonstrated her measurement strategy. Once the demonstrations were complete, Tiffany said, "Sit like morning meeting so we can talk about our

observations." She continued, "Tell me what you noticed. Would you think that was an accurate way to measure?" She then allowed the students to share their observations and offer suggestions for how the measuring would be more accurate. Tiffany summarized the students' suggestions stating, "Remember, we talked about the importance of accuracy with measurement around the world. Make sure the ruler is at the very end. You have to mark it."

Lillian used a similar strategy when two students presented a solution in which the model, the equations, and the student explanations did not match. Lillan instructed the students to, "Turn toward your partner and figure out what happened. How does this strategy compare to what Laney shared?" She then facilitated a discussion that helped the students clarify their thinking.

The sociomathematical norms (Yackel & Cobb, 1996) exemplified in Lillian and Tiffany's teaching practices are reflected in the *Mathematics Teaching Practices* (NCTM, 2014) in which teachers implement tasks that promote reasoning and problem solving (Practice #2), use and connect mathematical representations (Practice #3), facilitate meaningful mathematical discourse (Practice #4), pose purposeful questions (Practice #5), build procedural fluency from conceptual understanding (Practice #6), and elicit and use evidence of student thinking (Practice #8). The sociomathematical norms and *Mathematics Teaching Practices* share commonalities with the STEAM instructional approaches. Namely, STEAM instructional approaches prioritize problem solving, authentic tasks, inquiry, process skills, student choice, and integration.

Conversely, the nature of the mathematical discourse that occurred in Rebecca and Stephanie's classrooms was teacher-directed. They demonstrated a "calculational" orientation toward mathematics teaching by focusing on the problem to be solved, prioritizing the answer, and maintaining expectations for student explanations that were shallow and incomplete (Thompson, Thompson, & Boyd, 1994). The teachers led the conversations and explicitly modeled mathematical representations with no explanation of how the representations were related to each other or to the mathematics. They quickly corrected student errors with no explanation on the part of the teacher or the student of where the flaw in thinking occurred.

Rebecca and Stephanie did express the belief that student talk should play a major role in mathematics teaching and learning.

Rebecca explained:

Student talk is huge. For example, this morning with that worksheet there would be a child who didn't get it and so the rest of the table, they were explaining it to them how they needed to complete the worksheet for morning work. You can just sit back and listen and it's very interesting to see how the way I explain it to them may not necessarily be how their peers explain it. Their peers might explain it better than I can, just because they're on the same level. Um, so the kids, I mean, in every center for math they're constantly talking. They're talking it out. So, for instance, at the light table they're building structures of MagnaTiles. They have to communicate and talk about what they want to build and who's going to

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use what pieces because we don't have a thousand pieces. So they have to share, they have to talk it out. They have to, you know, use math talk to build a structure that's going to stand and not fall over. Um, same thing with Legos, same thing with if they're doing a puzzle, you know, "Who has this piece?" They're looking at different flat sides and curved sides on puzzles. They're constantly talking about math. They don't realize it, but as a teacher if I sit back and listen, they really are talking a lot and a lot of it is problem solving. "How can we work together to create a structure? How can we work together to finish a puzzle?" or "How can I tell you how to complete this sheet because you're just not getting it?" So, I think it's huge, I mean especially in kindergarten and especially because we do centers. They have that opportunity to talk, where in past times, I've taught math whole group and there's no talk. They just, it's me talking and them answering questions and I feel like having math centers in kindergarten has really helped open up the talking and problem solving among peers.

Contrary to the beliefs expressed by Rebecca and Stephanie, the nature of the mathematical discourse that was observed in each of the classrooms was teacher-directed and teacher-centered. For example, while guiding students through applying both the number line strategy and the counting on strategy, Stephanie asked very rote and predictable questions such as "Did he start in the right spot? How many hops? What's the sum?" and "What do I put in my head? Count up how many times?" Rebecca instructed the students, "Write it on your

board, don't tell me." The following exchange between Rebecca and her students exemplifies the teacher-centered nature of the discourse in these two classroom.

Student: "I know what six plus six is!"

Rebecca: "You do? What is it?"
Student: "Twelve!"

Rebecca: "Good." Hushes other students who are trying to join in the conversation reminding them, "Make sure you have a bubble in your mouth."

While Rebecca and Stephanie utilized different representations for mathematics problems such as the ten-frame and the number line, the focus was on the representation itself, not on the use of the representation as a tool for facilitating mathematical discourse or understanding mathematics. Both teachers modeled explicitly how to "do" the strategy. Rebecca modeled the use of the ten-frame stating, "We have an empty ten-frame. How many dots are missing? Remember, where do you start when you're filling in your ten-frame? Do you start at the bottom? No, you start at the top." The students then copied the ten-frame in their number books. Similarly, Stephanie modeled the use of the number line for addition repeatedly instructing the students to "start with the biggest number and count up."

Finally, Rebecca and Stephanie treated students' errors much differently than Lillian and Tiffany. While the nature of Lillian and Tiffany's mathematical discourse reflected sociomathematical norms (Yackel & Cobb, 1996) by capitalizing on student errors as opportunities for discourse to clarify and deepen

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mathematical understanding, Rebecca and Stephanie quickly corrected errors and moved on. Rebecca responded to one situation stating, "Okay, we've got two different answers. Would we say 1, 2, 3 or 1, 4, 3?" In another situation she responded, "You're guessing, not taking your time." Stephanie responded to one student's proclamation that "There were 1006 noodles" by saying, "There were not 1006 noodles!"

Theme 2.c.: Inconsistencies in espoused and enacted beliefs.

There were clear differences in both the expressed beliefs and enacted practices in relation to the roles of teachers and students. Lillian and Tiffany assumed the role of facilitators of learning. They monitored student work and discussions, listened to their students, asked probing questions, and served as facilitators of discourse. Lillian believes in "taking the time to listen to kids' answers." She described the role of the teacher in a mathematics classroom by stating, "The teachers would be kind of like listening to what students were saying, stopping to ask for clarification, like, 'How do you do this?' or 'Tell me why you did this.'" She continued, "The teacher is checking in, making sure that each person is doing what they're supposed to be doing, but also pressing for further understanding, like, 'How did you get that?' 'How did you know to do that?'" This view of the teacher's role was evident in both Lillian and Tiffany's classroom. The teachers also assumed the responsibility for teaching the students how to participate in productive mathematical conversations. Lillian explained, "I would kind of like help them have the conversation, like, well, 'let's talk about what you did' and you show your strategy and then you let them share

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theirs again." They consistently used phrases and questions such as, "Okay, Caleb, tell me about your strategy." and "How do you know when you need to regroup?"

Lillian consistently probed students' understanding as evidenced in the following:

Can you say that one more time? And where did you get the 7? What part of the problem told you to get the 7? So what did you do with the 7? Hang on, so you said you had 7 on your fingers so you put 3 more, tell us about that.

Lillian and Tiffany both placed much of the responsibility for developing mathematical understanding on their students.

Tiffany explained:

I really put a huge responsibility on them for listening and being receptive to other people's ideas because they may can find an easier way to do things…they learn how to listen, how to ask questions about whatever it is that they are explaining. I think it's important for that to happen.

Tiffany displayed this belief in her practice asking the students, "I'm just wondering where you got this 17 from? The answer is correct, but I have to know how you got it." Lillian painted a picture of the roles students play in a mathematics classroom in stating, "Having a real world problem and the kids are analyzing that problem, the kids are talking about that problem, kids are solving

that problem in different ways. Um, kids are talking about their solutions." She

continued, "Students are sharing their strategies. Other students ask questions,

other students make connections to either their strategy or other people's

strategies." The expectations that Lillian and Tiffany held for their students were

clearly stated. Table 4.19 provides samples of these expressed expectations.

Table 4.19 *Lillian and Tiffany's expectations for students*

"You can use whatever tools you have in front of you, but you have to prove your answer. Don't forget that you have to be able to prove it."
"It's quiet in here, I should hear your voices explain how you solved the problem and how you can prove it."
"Mathematicians have to justify. Just saying, 'my brain told me so' is not justification."
"Remember, we are being respectful, thinking in our head how the strategy works, and how we can use it ourselves."
"As you are listening to these strategies you should be thinking about how these strategies work, if you agree or disagree, and how they relate to your strategy."

The expectations that Lillian and Tiffany held for their students, once

again, reflected sociomathematical norms (Yackel & Cobb, 1996). Specifically,

they expected for their students' explanations to consist of mathematical

arguments and demonstrate understandings among multiple strategies.

Rebecca and Stephanie both expressed the beliefs that the role of the

teacher is to "model" and "help" students develop independence.

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Rebecca described her idea of "the best mathematics classroom" saying:

I would expect the teacher to be working with small groups and the rest of the kids in some type of center or small group setting working independently on skills that they have already gotten a foundation by working with the teacher.

Stephanie portrayed the view that it is the teacher's responsibility to "give" the students what they need in stating:

Most of the time I'd say the teacher would be working on a small group to kind of intervene, but sometimes you could see the teacher not as much like the focal point, but making sure that the class is managed and facilitating the learning by giving the kids what they need to do to solve the problems…just making sure that the kids, you know, kind of wondering around making sure that their conversations are on task and clearing up any misconceptions she sees while they're working.

Stephanie also explained:

Once I think, like, a standard is taught and understood to a certain amount I think the kids can kind of take ownership of their learning a little bit more. I don't think that you would see that classroom scenario right off the bat. I think you would see more whole group lessons at the beginning of the unit, but as the year goes on I would expect to see more of, um, you know, child-centered learning.

Unlike their other beliefs, the beliefs that were stated by Rebecca and Stephanie about the roles of teachers and students aligned with their enacted practices. In both the initial and final observations, Rebecca's class was organized in "rotations" in which the students spent twelve minutes with the teacher receiving direct instruction and the remainder of the time in independent learning centers. In the final observation, Rebecca pulled small groups and explicitly modeled how to complete the "Mistery Picture" sheet. She instructed, "Color in the number six." She then colored in the number six on her paper while the students mimicked her actions. She told the students, "You have to pay attention. If you watch Mrs. [Rebecca] you'll know."

Stephanie also demonstrated her belief that you have to help students before they are able to solve problems. For example, when she encountered a student who was having difficulty solving a problem she told her what number to "put in her head" and how many to "count on."

Finding three: Integration and authentic, real world situations.

Teaching in a STEAM school strengthened teachers' beliefs about the importance of integration and connecting mathematics to authentic, real world situations. At the end of the study, the teachers expressed beliefs about the importance of situating mathematics in the real world and reported an increased awareness of the importance of integration.

Theme 3.a.: Beliefs about situating mathematics in authentic, real world situations.

In the final interview, the teachers expressed beliefs about the importance of situating mathematics in authentic, real world situations. Lillian emphasized the importance of using relevant, authentic, real world problems. She insisted, "[Students best learn mathematics] when they're given real world situations that mean something to them." In her description of what constitutes mathematical understanding and proficiency she continued to emphasize the role of real world problems. She insisted, "If they can't apply it to a real situation then they probably don't even really understand what it means." Stephanie also focused more on students' ability to connect mathematics to the real world. She insisted that mathematical proficiency means "being able to use math problems in real world situations...they're just using it during their everyday conversations…It's not on a test. Whenever they're just using it during their everyday conversations." Tiffany also emphasized the importance of students being able to connect the mathematics that they are learning to the real world. She explained, "I think they realize as we talk about mathematics how to use math in the everyday world, that it's not isolated." Tiffany added, "I think as far as real world situations that the STEAM explorations that we do lend themselves to it…I think it probably makes things more real and logical for the children."

Theme 3.b.: Increased awareness of the importance of integration.

Teachers reported an increased awareness of the importance of integration. Lillian reflected on her experience in the STEAM school, "I do think it encourages me to think harder about making connections across the curriculum…definitely real world and just thinking about, like, what the kid is getting from it." Rebecca expressed a similar sentiment in stating, "Now I feel like my eyes have been really opened and I try to pull in STEAM throughout the entire day…I definitely think I am more willing to integrate math into other areas." Tiffany explained that teaching in a STEAM school has influenced her mathematics teaching by making her more aware of integrating and the importance of situating learning in the real world.

She explained:

I think thinking and planning more strategically that I am more aware…I'm more aware of integrating everything that we're doing…I think it provides more of an in depth process for planning of trying to make everything connect and so I think that would be growth.

Finding four: Enacted practices.

Teaching in a STEAM school influenced teachers' enacted practices in relation to situating mathematics in authentic, real world situations. Teachers used students' names and timely and shared experiences when posing problems and emphasized the use of mathematics in the real world.

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Theme 4.a.: Use of student names and timely and shared experiences in problems.

Teachers used students' names and timely and shared experiences when posing problems. In her final observation, Lillian used the names of first grade teachers and a timely and shared experience (composting) that was a part of the first grade spring STEAM unit. Tiffany and Rebecca also use real names in the problems that the presented to the students. Table 4.20 illustrates these real world problems.

Table 4.20 *Real world problems*

"Mrs. Rebecca went to the pumpkin patch and picked 3 pumpkins, dropped 1, how many are left?"
"Luke bought twenty-five cookies. He gave his sweetheart eight of the cookies. How many cookies does Luke have now?"
"Ms. Elizabeth's class put 7 apples in the compost bin. Ms. Lillian's class put 8 more apples in the compost bin. How many apples are in the compost bin?"

Theme 4.b: Mathematics in the real world

In the final interview, teachers emphasized the use of mathematics in the real world. While Stephanie revealed doubts in the initial interview about the influence that teaching in a STEAM school would have on mathematics teaching, her responses to similar questions in the final interview revealed the belief that authentic, real world problems should play a major role in mathematics teaching and learning.

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She reflected:

I think math is so important is whenever they're using it to solve real world problems. I think that's the whole idea behind STEAM. That they are taking their learning and trying to solve something larger and then they notice their impact on it. I think that's what's great about the STEAM school …We have the opportunity to have guest speakers that go along with our project and then it gave the kids a whole new appreciation for why we're learning math and why it's so important in how they're going to use it when they're adults and it makes it a little more relevant. I think it makes kids more passionate when they understand the reason they have to know something is because they're going to use it later on. It's not just temporary knowledge…After we had that one speaker, I had a student that I was struggling to reach an interest with and he really thought it would be great to be a coastal engineer. He wrote in his journal about how he is going to work so hard in math because that's what he wants to be. I think it gave him a little more willpower to work hard and study and learn those facts just so that he could become what he wanted to be. That's kind of powerful.

Tiffany also emphasized the importance of connecting mathematics to the real world. In her final observation lesson, she initiated a discussion about why it is important to measure precisely in the real world. She asked, "How could I use this in the real world? What's something that could cause major problems?" "Why would I be measuring this rug in the real world?" She then gave the students an

opportunity to discuss the reasons why someone would have to measure the rug. Next, she encouraged the students to "Tell me something in your real life." One student said, "Medicine!" Tiffany probed, "Why?" Tiffany then facilitated a discussion about why it is important to measure medicine carefully.

Discussion

The analysis of the data collected in this study revealed four major findings. Namely, this study revealed: (1) Teachers in a STEAM school expressed similar and consistent beliefs about the teaching and learning of mathematics that are considered productive in light of reform efforts. (2) Teachers in a STEAM school enacted divergent practices. (3) Teaching in a STEAM school strengthened teachers' beliefs about the importance of integration and connecting mathematics to authentic, real world situations. (4) Teaching in a STEAM school influenced teachers' enacted practices in relation to situating mathematics in the real world. Table 4.21 provides an overview of each finding in relation to the research question they support and the data sources that were used for triangulation.

Table 4.21 *Matrix of findings and sources for data triangulation*

Major Findings	Sources of Data		
	O	I	S
Question 1: What are the beliefs about the teaching and learning of mathematics held by elementary mathematics teachers situated in a STEAM school?			
Finding 1: Teachers in a STEAM school expressed similar and consistent beliefs about the teaching and learning of mathematics that are considered productive in light of reform efforts.			

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	O	I	S
Theme 1.a. Participants in this study consistently expressed beliefs that the standards, multiple teaching practices, including hands-on and differentiation, and a focus on multiple solution strategies are essential elements of quality mathematics teaching and learning.	X	X	X
Theme 1.b. The participants in this study expressed common beliefs about what constitutes mathematical understanding and proficiency. The participants, as a whole, believe that mathematical proficiency consists of a balance of procedural fluency and conceptual understanding. They also consistently reported using students' success with the standards as a measure for mathematical proficiency. Additionally, the participants in this study consistently expressed the belief that students demonstrate mathematical understanding by solving problems and representing numbers in multiple ways. The teachers also collectively regard risk taking and perseverance as an aspect of mathematical understanding and proficiency.	X	X	X
Question 2: How does teaching in a STEAM school influence the enacted practices and beliefs of teachers about teaching and learning mathematics?			
Finding 2: Teachers in a STEAM school enacted divergent practices.			
Theme 2.a There were clear differences in task selection and implementation.	X	X	
Theme 2.b. The use of mathematical discourse was area where divergent practices emerged.	X	X	
Theme 2.c.There were clear differences among the teachers in relation to the roles of teachers and students in a mathematics classroom.	X	X	
Finding 3: Teaching in a STEAM school strengthened teachers' beliefs about the importance of integration and connecting mathematics to authentic, real world situations.			
Theme 3.a.Teachers expressed beliefs about the importance of situating mathematics in authentic, real world situations.		X	X
Theme 3.b. Teachers reported an increased awareness of the importance of integration.		X	
Finding 4: Teaching in a STEAM school influenced teachers' enacted practices in relation to situating mathematics in the real world.			
Theme 4.a. Teachers used students' names and timely and shared experiences when posing problems.	X	X	
Theme 4.b. Teachers emphasized the use of mathematics in the real world.	X	X	

Note: In this table, O=observations, I=interviews, S=survey.

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The shared beliefs expressed by participants in the study show that there are certain beliefs that are valued in this STEAM setting. As noted in Chapter 2, the situated learning theory views learning and knowledge as embedded in social contexts and experiences, and promoted through interactive, reflective exchanges among participants in the community of practice. The finding of these widely held beliefs held by teachers in a STEAM school illustrates what is valued in the setting. The teachers expressed beliefs that are aligned with reform-oriented practices in mathematics education. The participants in this study believe that the content standards, use of multiple instructional strategies, including hands-on and differentiation, and a focus on multiple solution strategies are essential elements of quality mathematics teaching and learning. The participants also expressed common beliefs about what constitutes mathematical understanding and proficiency. The participants, as a whole, believe that mathematical proficiency consists of a balance of procedural fluency and conceptual understanding. They also consistently reported using students' success with the content standards as a measure for mathematical proficiency. Additionally, the teachers expressed the belief that students demonstrate mathematical understanding by solving problems and representing numbers in multiple ways. Finally, the teachers collectively value specific student dispositions including risk taking and perseverance. These views are valued by the individuals in the setting and reinforced and promoted through exchanges and experiences that occur within the community of practice. This finding is important because of the role that teachers' beliefs play in their enacted practices.

Teaching in a STEAM school cultivates reform-oriented beliefs and, in time, offers promise in cultivating reform-oriented practices.

The analysis of the data collected in this study also revealed the finding that some teachers in a STEAM school enacted divergent practices. Specifically, some teachers enacted reform-oriented practices while others enacted traditional/transmission-oriented practices. Lillian and Tiffany enacted reform-oriented teaching practices that were in alignment with their beliefs while Rebecca and Stephanie enacted practices that lacked alignment with their beliefs.

There were clear differences in how the two pairs of teachers selected and implemented problem solving tasks in their teaching practices. Lillian and Tiffany used problem solving tasks as curricular resources for advancing student learning. They used authentic, real world problems to provide students with opportunities develop and deepen their own mathematical understanding. The focus in Lillian and Tiffany's classrooms was on understanding the problem and being able to explain and justify solutions. Rebecca and Stephanie, on the other hand, utilized isolated problems that were void of any real world connections to model explicit procedures for solving problems. These differences are important because not all tasks provide the same opportunities for developing mathematical understanding. NCTM (2014) explains, "Effective teachers understand how contexts, culture, conditions, and language can be used to create mathematical tasks that draw on students' prior knowledge and

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experiences or that offer students a common experience from which their work on mathematical tasks emerges" (p. 17).

The use of mathematical discourse was another area where divergent practices emerged. The discourse that occurred in Lillian and Tiffany's classrooms was student-centered. Conversations were student initiated and student led. Students were expected to explain and justify their solutions and to use different representations to support those explanations. Additionally, Lillian and Tiffany capitalized on student errors as opportunities to clarify and deepen mathematical understanding. Conversely, the discourse that occurred in Rebecca and Stephanie's classrooms was teacher-directed. The teachers led the conversations and explicitly modeled mathematical representations with no explanation of how the representation was related to the mathematics. They quickly corrected student errors with no explanation on the part of the teacher or the student of where the flaw in thinking occurred.

Finally, there were clear differences in both the beliefs and enacted practices in relation to the roles of teachers and students. Lillian and Tiffany assumed the role of facilitators of learning. They monitored student work and discussions, listened to their students, asked probing questions, and served as facilitators of discourse. Rebecca and Stephanie both expressed the beliefs that the role of the teacher is to "model" and "help" students develop independence. Their enacted practices aligned with these beliefs.

The divergence in practices may be attributed to two factors. First, the reform-oriented teachers, Lillian and Tiffany, displayed more reflectiveness in

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their interview responses than Rebecca and Stephanie. Second, Rebecca and Stephanie's interpretations of practices advocated by reform was different from the intent of the reform efforts.

Lillian and Tiffany demonstrated reflective practices through their interview responses. First, they both reflected on their own experiences with mathematics teaching and learning. Lillian reflected on her own experiences learning math as an elementary student.

She implied that she wanted to offer different experiences to her students in stating:

I remember having to do random things in math when I was in elementary school that made zero sense to me and I just did it because that's what I was told and so I feel like it's just kind of the opposite of that.

Tiffany reflected on her experiences with math explaining, "I don't think [a good mathematics teacher] has to be a person who did well in math because I think I've put more planning into math because I did not like math very much."

Lillian and Tiffany also openly reflected on areas where they would like to improve their teaching practice. Lillian explained, "In our STEAM plan we were weak in math. So, we weren't able to make strong connections in math which I think we can get better at". She also added that she needs to work on "finding time for differentiation too." Tiffany reflected, "I haven't used a lot of small groups within the math class, but I think that would be a good way to explore that and, you know, maybe have some stations set up like I do in literacy."

It was also evident that the influence of teaching in a STEAM setting was an area of much reflection for the pair. Lillian expressed her hopes for the influence that teaching in a STEAM school would have on her practice.

She explained:

I hope that it becomes more of, like, a combination of stuff and not just, like, here's our math time, here's our science time, here's our whatever time. I do hope it becomes more project based where we're, like, being able to tie it kind of all together so it's not quite so isolated. I feel like it's still kind of pretty isolated, um, so I'm hoping that through, like the sea turtles project, we were able to weave some of it in. This was our first project so I didn't expect it to be perfect, but, um, I do hope it becomes more of, like, really starting with a problem and, like, being able to use our math to solve things in science or, you know, whichever subject. I definitely hope it becomes more integrated.

Lillian's reflection on the influence of STEAM helped her to see that she may need to reframe some of her thinking about the standards.

She explained:

I get locked into the standard sometimes. I'm like back and white, like "that's my standard and this is what I need to do." It's forcing me to think from another, like, way, like coming in to the standard from another outlet. Like of the students' interests or whatever based on what we're doing in STEAM.

Tiffany's reflection on the influence of teaching in a STEAM school confirmed her practices, but also help her to identify areas where she would like to improve.

She explained:

So it's like confirming that these are good practices. Um, I think that, um, with literacy I'm more in tune to reading articles and keeping up with it and, um, I need to do the same thing with math. And, um, explore more, because, um, there are a lot of different ways that children learn and stuff.

Tiffany described the influence of teaching in a STEAM setting by saying, "I think thinking and planning more strategically that I am more aware…I'm more aware of integrating everything that we're doing." Lillian echoed, "I do think it encourages me to think harder about making connections across the curriculum." Tiffany also reflected on her areas of strength, "I think probably a strong point for me is that I play on whatever moment arises."

There was much less reflection evident in Rebecca and Stephanie's interviews. The reflection that did occur was focused more on the characteristics and restraints of particular settings than on individual characteristics and practices. Rebecca's reflections about the influence of teaching in a STEAM setting focused much more on the environment than on her own practice.

She explained:

Now that I have the options to do the small groups and to pull in the STEAM throughout even my math centers, my kids love learning so much

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more and I have seen so much more progress now that I've changed the way that I teach…I think this whole opportunity has really opened my eyes and allowed me to become a better teacher and I can look back and now reflect on how I used to teach and see the difference.

This reflection indicates that it is the environment that has changed, not her. Similarly, Stephanie focused more on how things were done in her other school explaining, "Sometimes we just taught something and then kind of moved on." Stephanie also expressed confusion when asked how she perceived that teaching in a STEAM school would influence her practice.

She explained:

Um, I don't know that it will really affect it. I think I usually teach a variety of strategies and it kind of depends on the students on what kind of strategy they pick up on. I don't know that the strategies are as much based on STEAM as, like, by the individual students and, like, what clicks for them. Because whenever it's primary math and it's pretty cut and dry I don't know that, um, I guess that the STEAM wouldn't influence the strategies as much.

Rebecca and Stephanie demonstrated attempts to incorporate reform-oriented practices in their classrooms. They presented students with problems, utilized models and representations, and asked questions throughout their instruction. However, the ways in which they enacted these practices were not in alignment with the intent of reform efforts. Rebecca and Stephanie, instead,

displayed teacher-centered practices in which the teacher provided direct instruction on explicit mathematical procedures and ask rote, predictable questions.

The analysis of the data in this study also found that teaching in a STEAM school strengthens teachers' beliefs about the importance of integration and connecting mathematics to the real world and influences teachers' enacted practices in relation to situating mathematics in the real world. These findings offer promise for situating mathematics teachers' learning in a STEAM setting to cultivate reform-oriented practices.

Summary

This study revealed four major findings in relation to the research questions: (1) Teachers in a STEAM school expressed similar and consistent beliefs about the teaching and learning of mathematics that are considered productive in light of reform efforts. (2) Teachers in a STEAM school enacted divergent practices. (3) Teaching in a STEAM school strengthens teachers' beliefs about the importance of integration and connecting mathematics to authentic, real world situations. (4) Teaching in a STEAM school influenced teachers' enacted practices in relation to situating mathematics in authentic, real world situations. Each finding was corroborated by multiple data sources, providing a more comprehensive understanding of the beliefs held by mathematics teachers situated in a STEAM setting about mathematics teaching and learning and the practices they enact as well as the influence the a STEAM setting has on teachers' beliefs and enacted practices.

This chapter provided a thick-rich description each teacher, presented the findings in relation to each of the research questions, and provided a discussion of the findings.

CHAPTER 5

FINDINGS AND DISCUSSION

Research has demonstrated that teachers' beliefs about the nature of mathematics and mathematics teaching and learning play a key role in teachers' effectiveness and instructional decision-making, including the practices they enact (Ernest, 1989; Ball, 1991; Richardson, 1996; Fennema & Franke, 1992; Pajares, 1992; Thompson, 1992). The reform movement in mathematics education advocates student-centered instructional practices that prioritize inquiry, problem solving, understanding, and discourse (NCTM, 2000; NCTM, 2014; Ma, 2010; Peressini et al., 2004). The beliefs that teachers hold about the teaching and learning of mathematics influence the degree to which teachers enact reform-oriented instructional practices.

Many elementary mathematics teachers hold beliefs about the teaching and learning of mathematics and enact practices that are not aligned with the recommendations of reform efforts in the field of mathematics education (Stigler & Hiebert, 2009; Polly et al., 2013). While the standards-based reform movement began in the 1980's, only minimal change has occurred at the classroom level in important areas that affect children (Herrera & Owens, 2001). For standards-based reform to gain any significant success, many teachers will have to alter the deeply held beliefs that they have about mathematics teaching and learning (Ellis

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& Berry, 2005). Additionally, the influence of a STEAM setting on mathematics teachers' beliefs and practices is not well understood. On the other hand, STEAM instructional practices and the mathematics reform movement share overlapping and complementary goals—achieving success with one will likely have a positive effect on the other.

Purpose of Study

Given the role that teachers' beliefs about the nature of mathematics and mathematics teaching and learning play in their selection and enactment of instructional practices, it is essential to understand the influence that different school settings may have on developing and changing teachers' beliefs and practices. The STEAM setting is of particular interest because of its emphasis on problem solving and its emerging popularity in the field of education.

This research project investigated the beliefs and enacted practices related to the teaching and learning of mathematics held by elementary mathematics teachers situated in a STEAM school. I pursued this study to gain an understanding of how elementary mathematics teachers positioned in a STEAM school view mathematics teaching and learning in an environment that supports reform-oriented practices through prioritizing science, technology, engineering, arts, and mathematics in a real world, problem-based, transdisciplinary approach to learning.

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Research Questions

Specifically, the research questions were:

- What are the beliefs about the teaching and learning of mathematics held by elementary mathematics teachers situated in a STEAM school?

- How does teaching in a STEAM school influence the enacted practices and beliefs of teachers about teaching and learning mathematics?

The RTOP scores, along with the detailed field notes, helped to develop a thick-rich description of the enacted practices for each participant. The data were also analyzed to identify themes in enacted practices as well as any changes that were observed in enacted practices.

I conducted semi-structured interviews to explore teachers' beliefs about teaching and learning mathematics, perceptions about how teaching in a STEAM school influences those beliefs, and how beliefs and experiences in a STEAM school influence the instructional practices they employ. Each teacher in the study was interviewed twice, once in October 2016 and once in January/February 2017. The initial interview focused on teachers' existing beliefs related to mathematics teaching and learning and their perceptions of how teaching in a STEAM school may influence those conceptions and, in turn, their enacted practices. The final interview focused on how the teachers perceived the influence that teaching in a STEAM school had on their beliefs about teaching and learning mathematics as well as their enacted practices. The interviews

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were semi-structured with common questions asked of all teachers to provide consistency across teachers. Follow-up questions were asked based on individual teachers' responses. The interview data were used to develop thick-rich descriptions of the beliefs about mathematics teaching and learning and perceptions about the influence of teaching in a STEAM school for each participant. The data were also analyzed to identify themes in teachers' beliefs about mathematics teaching and learning as well as any changes that occurred in beliefs about mathematics teaching and learning.

Finally, Scoop Notebooks were collected. There were two ten day Scoop periods during the data collection phase of the study (one in September 2016 and one in January 2017). I used these documents and artifacts as a compliment to the interviews and observations.

Data analysis.

I approached the data analysis through the lens of reform-oriented beliefs and practices outlined in the literature in the field. Namely, I identified evidence of constructivist/reform-oriented beliefs and evidence of traditional/transmission-oriented beliefs. I utilized the *Eight Mathematics Teaching Practices* (NCTM, 2014) as a framework for reform-oriented practices and identified evidence of each practice. I began the data analysis process by reading and memoing each piece of data to get a sense of the whole database. Following the advice of Agar (1980), I immersed myself in the details to get a sense of the whole before I broke it into parts. In the analysis of the interview transcripts, the observations, and the documents/artifacts I drew inferences from what participants said and did

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during the interviews and observations (Pajares, 1992) and considered the documents and artifacts in terms of form, function, and symbol within specific contexts (Glesne, 2011). I remained aware that "respondents answer questions in the context of dispositions (motives, values, concerns, needs) that researchers need to unravel to make sense out of the words that their questions generate" (Glesne, 2011, p. 102). I wrote memos, including phrases, ideas, or key concepts that occurred to me as I was reading, in the margins and under photographs. I then scanned the database to identify major organizing ideas and formed initial categories by reflecting on the larger thoughts presented in the data and looked for multiple forms of evidence to support each thought. Next, I moved into the spiral of describing, classifying and interpreting the data. I did this by forming codes. Through coding, I worked to build detailed descriptions, develop themes, and provide an interpretation in light of my own views and the views presented in the literature. Specifically, I coded evidence of constructivist/reform-oriented beliefs, evidence of traditional/transmission-oriented beliefs, and evidence of the *Eight Mathematics Teaching Practices* (NCTM, 2014). I developed the codes by "aggregating the text or visual data into small categories of information, seeking evidence for the code from different data bases being used in the study, and then assigning a label to the code" (Creswell, 2013, p. 184). I then developed a short list of codes and worked to reduce and combine them into themes. In establishing the codes, I searched for relationships between the data and created a thematic organizational framework that highlighted the data that applied to the research purpose. Once the codes were established, I continued to explore the

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relationships between the data by analyzing "how categorizations or thematic ideas represented by the codes vary from case to case, from setting to setting or from incident to incident" (Gibbs, 2007, p. 48). Creswell (2013) describes themes as "broad units of information that consist of several codes aggregated to form a common idea" (p. 186). Throughout the entire process, I looked for information in the data that would help me form a deep description of this particular case. Themes emerged from this process that were grounded in analysis and data. I then created a table for each theme and organized the quotes, artifacts, and classroom description under each theme.

Next, I engaged in interpreting, or making sense, of the data.

Cresswell (2013) explains:

Interpretation in qualitative research involves abstracting out beyond the codes and themes to the larger meaning of the data. It is a process that begins with the development of the codes, the formation of themes from the codes, and then the organization of themes into larger units of abstraction to make sense of the data. (p. 187)

I linked the interpretation to the larger literature base and represented the data by packaging "what was found in text, tabular, and figure form" (Creswell, 2013, p. 187).

Establishing Trustworthiness

Establishing trustworthiness is an essential component of qualitative research (Lincoln & Guba, 1985; Glesne, 2011). In this study, I employed several

techniques to establish trust in the findings. To increase the probability of high credibility, I engaged in prolonged engagement, persistent observation, triangulation, and member checking. My role as the instructional coach at the school gave me the opportunity to engage with the participants on a daily basis. The prolonged engagement was an essential component in establishing trust and rapport with the participants. Additionally, this technique helped me to learn the context and culture, and minimize distortions (Lincoln & Guba, 1985, Creswell, 2014). The persistent observation technique helped me to identify the characteristics and elements in the situation that were relevant to the research questions and focus on them in detail. The credibility of the study was strengthened by triangulation of different data collection methods (i.e. interviews, observations, artifacts, surveys). This technique also proved useful in identifying and corroborating emerging themes in the data (Creswell, 2013). Additionally, I used the technique of member checking to gain the participants' views on the credibility of the findings. I provided thick descriptions of the case and the setting to increase the transferability. The use of purposeful sampling provides a data base that "makes transferability judgments possible on the part of potential appliers" (Lincoln & Guba, 1985, p. 316).

The techniques employed to demonstrate credibility, prolonged engagement, persistent observation, triangulation, and member checking, also strengthen the dependability of this study. Lincoln and Guba (1985) explain, "If it is possible using the techniques outlined in relation to credibility to show that a study has quality, it ought not be necessary to demonstrate dependability

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separately" (p. 317). Confirmability of the study was increased through a detailed description of the data collection and analysis methods as well as explanations of how and why decisions were made throughout the study.

Chapter Organization

In the following sections, I will provide a discussion of the findings in relation to literature in the field. I will also identify and discuss implications for practice, recommendations for future research, and conclusions.

Discussion of Findings

The analysis of the data collected in this study revealed four major findings. Namely, this study revealed: (1) Teachers in a STEAM school expressed similar and consistent beliefs about the teaching and learning of mathematics that are considered productive in light of reform efforts. (2) Teachers in a STEAM school enacted divergent practices. (3) Teaching in a STEAM school strengthened teachers' beliefs about the importance of integration and connecting mathematics to authentic, real world situations. (4) Teaching in a STEAM school influenced teachers' enacted practices in relation to situating mathematics in authentic, real world situations. Each finding is described below in relation to the literature in the field.

Research Question 1

This study investigated the following research question: What are the beliefs about the teaching and learning of mathematics held by elementary

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mathematics teachers situated in a STEAM school? Two major findings emerged in relation to this question: (1) Teachers in a STEAM school expressed similar and consistent beliefs about the teaching and learning of mathematics that are considered productive in light of reform efforts. (2) Teachers in a STEAM school enacted divergent practices.

Finding one: Similar and consistent beliefs.

The shared beliefs expressed by participants in the study show that there are certain beliefs that are valued in this STEAM setting. As noted in Chapter 2, the situated learning theory views learning and knowledge as embedded in social contexts and experiences, and promoted through interactive, reflective exchanges among participants in the community of practice. The finding of these widely held beliefs held by teachers in a STEAM school illustrates what is valued in the setting. The teachers expressed beliefs that are aligned with reform-oriented practices in mathematics education. The participants in this study believe that the content standards, use of multiple teaching practices, including hands-on and differentiation, and a focus on multiple solution strategies are essential elements of quality mathematics teaching and learning. The participants also expressed common beliefs about what constitutes mathematical understanding and proficiency. The participants, as a whole, believe that mathematical proficiency consists of a balance of procedural fluency and conceptual understanding. They also consistently reported using students' success with the content standards as a measure for mathematical proficiency. Additionally, the teachers expressed the belief that students demonstrate

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mathematical understanding by solving problems and representing numbers in multiple ways. Finally, the teachers collectively value specific student dispositions including risk taking and perseverance. These views are valued by the individuals in the setting and reinforced and promoted through exchanges and experiences that occur within the community of practice.

The finding of these shared beliefs held by teachers in a STEAM school illustrate what is valued in the setting. In general, the teachers expressed beliefs that are aligned with reform-oriented practices in mathematics education suggesting that these views are valued by the individuals in the setting and reinforced and promoted through exchanges and experiences that occur within the community of practice.

The finding of commonly held beliefs among participants in this community of practice is consistent with the situated learning theory. The situated learning theory adopts the assumption that experiences of learning cannot be separated from the situated elements in which they occur (Lave, 1988), commonly referred to as *communities of practice*. Communities of practice are comprised of the community's unique ways of thinking, being, and doing (Wenger & Snyder, 2000). The social context of learning and social interaction among and between learners are important aspects of the situated learning theory. Lave (1988) explains that situated learning occurs as the function of an activity and the context and culture in which that activity is situated. He noted the importance of the social construct of learning and how people in groups acquire knowledge. The situated learning theory views learning not an isolated process, but, the

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construction of meaning as tied to specific contexts and purposes. Individuals and the world in which they live where events and activities happen cannot be separated. Therefore, learning is social and comes from the experience of participating in daily life. Lave (1988) argued that knowledge is socially defined, interpreted, and supported. Brown, et al. (1989) agree that knowledge is a product of a meaning-making process and cannot be separated from its context. "How a person learns a particular set of knowledge and skills, and the situation in which a person learns, become a fundamental part of what is learned" (Putnam & Borko, 2000, p. 4). Learning evolves as a result of membership in a group (Lave & Wenger, 1991). This aspect of situated learning focuses on how individuals, activities, and the world constitute each other within groups labeled as communities of practice (Lave & Wenger, 1991). "The term 'practice' is defined as the routine, everyday activities of a group of people who share a common interpretive community" (Henning, 2004, p. 143). From this point of view, learning is not only making meaning through practice in an activity or using tools or signs to understand activities but, more importantly, learning is co-constructed by members in the community. "The role of others in the learning process goes beyond providing stimulation and encouragement for individual construction of knowledge" (Putnam & Borko, 2000, p. 5). Therefore, knowledge is not an object and memory is not a location, instead, knowledge is located in the actions of people and groups of people. These interactions between members of a group determine both what is learned and how the learning takes place. Communities of practice have "a particular set of artifacts, forms of talk, cultural history, and

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social relations that shape, in fundamental and generative ways, the conduct of learning" (Henning, 2004, p. 143). These communities "provide the cognitive tools--ideas, theories, and concepts--that individuals appropriate as their own through their personal efforts to make sense of experiences" (Putnam & Borko, 2000, p. 5). In other words, learning is a process of enculturation in which individuals observe and practice behaviors of the members of a culture and adopt relevant jargon, imitate behaviors, and eventually behave in accordance with the norms of that culture. It is important to note that cultural models are not held by individuals, but live in the practices of a community and how individuals interact with one another. Consequently, as situations shape individual cognition, individual thinking and action, in turn, shape the situation through the ideas and ways of thinking that they bring to the situation. Brown et al. (1989) agree that the conceptual tools of a community of practice "reflect the cumulative wisdom of the culture in which they are used and the insights and experience of individuals" (p. 33). From this perspective, learning is viewed "as the ongoing and evolving creation of identity and the production and reproduction of social practices both in school and out that permit social groups, and the individuals in these groups to maintain commensal relations that promote the life of the group" (Henning, 2004, p. 143).

The finding of widely held, reform-oriented beliefs among participants situated in a STEAM setting is significant given the role that teachers' beliefs play in the successes and failures of reform efforts. The main obstacle to reform implementation is teachers' beliefs about the nature of mathematics and

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mathematics teaching and learning that are incompatible with those beliefs underlying reform efforts (Ross, Hogaboam-Gray, & McDougall, 2002; Polly, et al., 2013; Stigler & Hiebert, 2009). These prevailing beliefs serve as impediments to the current reform efforts in mathematics education (Goldin, Rosken, & Torner, 2009) and have been cited as the main reason for the failure of reform efforts (Schoenfeld, 1985). The finding that teachers situated in a STEAM school share reform-oriented beliefs about mathematics teaching and learning suggests that the STEAM setting cultivates teacher beliefs that are productive in light reform efforts in mathematics education.

Finding two: Divergent practices.

This study also revealed the finding that, while most of the beliefs expressed by the participants in the interviews and on the MECS surveys remained consistent and in alignment with teaching practices advocated in the reform movement, divergent practices emerged in the observations. Four participants, Lillian, Tiffany, Rebecca, and Stephanie, were used to illustrate these divergent practices. Lillian and Tiffany enacted reform-oriented teaching practices that were in alignment with their beliefs while Rebecca and Stephanie enacted traditional/transmission-oriented practices that lacked alignment with their beliefs. Specifically, evidence demonstrates that Lillian and Tiffany's enacted practices were reflective of the *Eight Mathematics Teaching Practices* (NCTM, 2014) that were used to frame reform-oriented mathematics teaching in this study. On the contrary, these practices were not evidenced in Rebecca and

Stephanie's enacted practices. The *Eight Mathematics Teaching Practices* include:

1. Establish mathematical goals to focus learning.

2. Implement tasks that promote reasoning and problem solving.

3. Use and connect mathematical representations.

4. Facilitate meaningful mathematical discourse.

5. Pose purposeful questions.

6. Build procedural fluency from conceptual understanding.

7. Support productive struggle in learning mathematics.

8. Elicit and use evidence of student thinking.

In the following discussion, I will cite the practices by their corresponding number. For example, I will refer to the practice of *establishing mathematical goals to focus learning* as Practice #1.

There were stark differences in the types of tasks that each pair of teachers posed to their students as well as in the implementation of the tasks. Lillian and Tiffany used tasks that promoted reasoning and problem solving as curricular resources for advancing student learning (Practice #2). These authentic, real world tasks provided students with opportunities to develop and deepen their own mathematical understanding, building procedural fluency from conceptual understanding (Practice #6). The focus in Lillian and Tiffany's classrooms was on understanding the problem and being able to explain and justify solutions. This is evidence of a conceptually-oriented stance toward teaching mathematics (Thompson, Thompson, & Boyd, 1994). Rebecca and

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Stephanie, on the other hand, utilized isolated problems that were void of any real world connections to model explicit procedures for solving problems evidencing a "calculational" orientation toward teaching mathematics teaching (Thompson, Thompson, & Boyd, 1994). Given that all mathematical tasks do not provide the same opportunities for student thinking and learning (NCTM, 2014), it is important to understand the how teacher orientations (conceptual and "calculational") influence the problem solving tasks that they select and the practices they use to implement the tasks.

The belief in the importance of using real world problems and connecting mathematics learning to authentic, real world situations was evident in the enacted practices of both Lillian and Tiffany. Both teachers presented problems to the students that included the names of students in the class and/or situations that were authentic to the classroom audience. It was evident that they understand "how contexts, culture, conditions, and language can be used to create mathematical tasks that draw on students' prior knowledge and experiences or that offer students a common experience from which their work on mathematical tasks emerges" (NCTM, 2014, p. 17). This view of implementing authentic, real world tasks is advocated by STEAM instructional approaches. Specifically, the problem-based nature of STEAM instructional approaches provides a context for learning, presents multiple lines of inquiry, and situates the learning in real world situations that reflect authentic and/or shared experiences for students. Authentic tasks address real world, timely, and local issues. It is also important to note that the word problems presented in Lillian and

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Tiffany's classrooms reflect those identified by Carpenter et al.'s (1999) *Classification of Word Problems* (e.g. Separate-Result Unknown). Lillian and Tiffany presented authentic, real world word problems to their students, encouraged students' intuitive use of strategies for solving the problems, and focused on these strategies for reflection and discussion. Cognitively Guided Instruction (CGI), as employed by Lillian and Tiffany, supported the implementation of tasks that promote reasoning and problem solving (Practice #2), the use of mathematical representations (Practice #3), meaningful mathematical discourse (Practice #4), building procedural fluency from conceptual understanding (Practice #6), and the use of student thinking (Practice #8).

The divergence in enacted practices were the most evident in the nature of mathematical discourse that was exemplified by each pair. Lillian and Tiffany exhibited a conceptually-oriented stance toward mathematics teaching while Rebecca and Stephanie exhibited a "computationally" oriented stance toward mathematics teaching (Thompson, Thompson, & Boyd, 1994). Specifically, Lillian and Tiffany focused "students' attention away from thoughtless application of procedures and toward a rich conception of situations, ideas, and relationships among ideas" (Thompson, Thompson, & Boyd, 1994, p. 46). Additionally, Lillian and Tiffany's expectations for student explanations reflected sociomathematical norms (Yackel & Cobb, 1996) that valued: 1) Explanations that consist of mathematical arguments, not simply descriptions of procedures or summaries of steps. (2) Capitalizing on errors as valuable opportunities for discussion,

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exploration, and reconceptualization. (3) Understanding the relationships among multiple strategies. (4) Collaborative work that involves individual accountability and consensus reached through mathematical argumentation. Students were expected to explain and justify their solutions and to use different representations to support those explanations. Additionally, Lillian and Tiffany capitalized on student errors as opportunities to clarify and deepen mathematical understanding.

The sociomathematical norms (Yackel & Cobb, 1996) exemplified in Lillian and Tiffany's teaching practices are reflected in the *Mathematics Teaching Practices* (NCTM, 2014) in which teachers implement tasks that promote reasoning and problem solving (Practice #2), use and connect mathematical representations (Practice #3), facilitate meaningful mathematical discourse (Practice #4), pose purposeful questions (Practice #5), build procedural fluency from conceptual understanding (Practice #6), and elicit and use evidence of student thinking (Practice #8). The sociomathematical norms and *Mathematics Teaching Practices* share commonalities with the STEAM instructional approaches. Namely, STEAM instructional approaches prioritize problem solving, authentic tasks, inquiry, process skills, student choice, and integration.

Conversely, the nature of the mathematical discourse that occurred in Rebecca and Stephanie's classrooms was teacher-directed. They demonstrated a "calculational" orientation toward mathematics teaching by focusing on the problem to be solved, prioritizing the answer, and maintaining expectations for student explanations that were shallow and incomplete (Thompson, Thompson,

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& Boyd, 1994). The teachers led the conversations and explicitly modeled mathematical representations with no explanation of how the representations were related to each other or to the mathematics. They quickly corrected student errors with no explanation on the part of the teacher or the student of where the flaw in thinking occurred.

This finding is consistent with research on conflicting beliefs and practices. Wilkins (2008) found that, for the majority of teachers, beliefs and practice were consistent. However, beliefs are not always consistent with instructional practices (Barkatsas & Malone, 2005; Ernest, 1989; Pajares, 1992; Thompson, 1992). Ernest (1989) offers three possible explanations for these inconsistencies: (1) depth of espoused beliefs and the extent to which they are integrated with knowledge and beliefs (2) teachers' consciousness of beliefs and extent to which the teacher reflects on practice (3) social context. Barkatsas and Malone (2005) attribute the inconsistencies to three major causes: classroom situations, prior experiences, and social norms. They explain that "a single element in the classroom situation, or the influence of societal and parental expectations, and teaching social norms can affect teaching practice to a greater extent than the teacher's espoused beliefs" (Barkatsas &Malone, 2005, p. 86).

The divergence in practices may be attributed to two factors. First, the reform-oriented teachers, Lillian and Tiffany, displayed more reflectiveness in their interview responses than Rebecca and Stephanie. Thompson (1984) found that differences in teachers' beliefs seemed to be related directly to differences in their reflectiveness. Reflectiveness in teaching can attribute to the integratedness

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of conceptions and the consistency between professed views and instructional practice (Thompson, 1984). When beliefs are formed through reflection teachers "gain possible insights into possible sources of her students' difficulties and misconceptions, thus becoming aware of the subtleties inherent in the content" (Thompson, 1984, p. 123). When teachers are not reflective "their beliefs seem to be manifestations of unconsciously held views or expressions of verbal commitment to abstract ideas that may be thought of a part of a general ideology of teaching" (Thompson, 1984, p. 124).

This study also revealed that Rebecca and Stephanie's interpretations of practices advocated by reform was different from the intent of the reform efforts. For example, both Rebecca and Stephanie demonstrated attempts to incorporate reform-oriented practices in their classrooms. They presented students with problems, utilized models and representations, and asked questions throughout their instruction. However, the ways in which they enacted these practices were not in alignment with the intent of reform efforts. Rebecca and Stephanie, instead, displayed teacher-centered practices in which the teacher provided direct instruction on explicit mathematical procedures and ask rote, predictable questions. Some researchers argue that because teachers often misinterpret reform recommendations, reform efforts may actually worsen the quality of instruction (Stigler & Hiebert, 2009). "Teachers often assimilate new ideas to fit their existing schemata instead of accommodating their existing schemata to internalize new ideas" (Philipp, 2007, p. 261).

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The misinterpretation of instructional practices advocated by the reform movement may be the result of the various influences that force teachers to prioritize among competing, and sometimes conflicting, values that result in beliefs about mathematics and mathematics teaching being overshadowed by more general educational priorities (Skott, 2001). Namely, teachers' beliefs about the roles of teachers and students may have a greater influence on the practices they enact than their beliefs about mathematics teaching and learning. Teachers hold very different views about the roles and responsibilities of students and teachers in the classroom. Reform-oriented teachers believe that students learn best by doing and learning mathematics on their own and that is the responsibility of the teacher to facilitate the learning while co-constructing knowledge through problems solving, questioning, and discourse (Peterson, et al., 1989). Lillian and Tiffany's enacted practices were consistent with reform-oriented beliefs about the roles of teachers and students. They both assumed the role of facilitators of learning. They monitored student work and discussions, listened to their students, asked probing questions, and served as facilitators of discourse. Rebecca and Stephanie, on the other hand, expressed the beliefs that the role of the teacher is to "model" and "help" students develop independence and enacted practices that were consistent with these beliefs. These beliefs and practices are consistent with those of traditional-oriented teachers who believe that it is the responsibility of the teacher to direct and control all classroom activities while the students are responsible for absorbing and processing given information. Teachers with this view typically demonstrate the process or provide

information, facts, laws, or rules that the students should follow and allow students time to work independently (Thompson, 1984). The finding that there were divergent practices in the STEAM setting that may be attributed to the teachers' level of reflectiveness and interpretation/misinterpretation of instructional practices advocated by the reform movement demonstrates consistency with findings in other settings.

Finding three: Integration and authentic, real world situations.

Teaching in a STEAM school strengthened teachers' beliefs about the importance of integration and connecting mathematics to authentic real world situations. At the end of the study, the teachers expressed beliefs about the importance of situating mathematics in authentic, real world situations and reported an increased awareness of the importance of integration.

In the final interview, the teachers expressed beliefs about the importance of situating mathematics in the real world. Lillian emphasized the importance of using real world problems. She insisted, "[Students best learn mathematics] when they're given real world situations that mean something to them." In her description of what constitutes mathematical understanding and proficiency she continued to emphasize the role of real world problems. She insisted, "If they can't apply it to a real situation then they probably don't even really understand what it means." Stephanie also focused more on students' ability to connect mathematics to the real world. She insisted that mathematical proficiency means "being able to use math problems in real world situations...they're just using it

during their everyday conversations…It's not on a test. Whenever they're just using it during their everyday conversations." Tiffany also emphasized the importance of students being able to connect the mathematics that they are learning to the real world. She explained, "I think they realize as we talk about mathematics how to use math in the everyday world, that it's not isolated." Tiffany added, "I think as far as real world situations that the STEAM explorations that we do lend themselves to it…I think it probably makes things more real and logical for the children."

The finding that being situated in a STEAM school strengthens teachers' beliefs about the importance of situating mathematics in authentic, real world contexts is important given the role that these contexts play in developing mathematical understanding in students. NCTM (2014) explain, "Effective teachers understand how contexts, culture, conditions, and language can be used to create mathematical tasks that draw on students' prior knowledge and experiences or that offer students a common experience from which their work on mathematical tasks emerges" (p. 17). The problem-based nature of STEAM provides a context for learning, presents multiple lines of inquiry, and situates the learning in real world situations. Namely, authentic tasks address real world, timely, and local issues that are relevant to the students and provide a context for problem solving in mathematics.

Teachers also reported an increased awareness of the importance of integration. Lillian reflected on her experience in the STEAM school, "I do think it encourages me to think harder about making connections across the

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curriculum…definitely real world and just thinking about, like, what the kid is getting from it." Rebecca expressed a similar sentiment in stating, "Now I feel like my eyes have been really opened and I try to pull in STEAM throughout the entire day…I definitely think I am more willing to integrate math into other areas." Tiffany explained that teaching in a STEAM school has influenced her mathematics teaching by making her more aware of integrating and the importance of situating learning in the real world.

> She explained:

> I think thinking and planning more strategically that I am more aware…I'm more aware of integrating everything that we're doing…I think it provides more of an in depth process for planning of trying to make everything connect and so I think that would be growth.

STEAM instructional approaches prioritize problem solving, authentic tasks, inquiry, process skills, student choice, and integration. The teachers' strengthening beliefs about the importance of integration and situating mathematics in the real world seems to stem from the positive effects that they perceive STEAM instructional approaches are having on their students. It is evident that changing one's beliefs is not normally the first option chosen (Goldin et al., 2009). The way beliefs are developed and held suggests that they may not be responsive to change through cognitive strategies including critical evaluation, external examination, and logical review (Grootenboer, 2008). Given the dynamics of teachers' beliefs, researchers and teacher educators must

understand that beliefs do not change as a result of argumentation or reason but rather through a "conversion or gestalt shift" (Nespor, 1987, p. 321). Grootenboer (2008) explains that for belief change to occur a teacher must both review the episodes that generated the belief and create new experiences where the desired belief is successful. Additionally, for belief change to occur a context in which it is emotionally safe to do so must be established (Goldin et al., 2009). The STEAM setting may provide this safe context.

The relationships between teachers' beliefs and practice are complex; each influences the other. Fennema et al. (1996) found that "there was no consistency in whether a change in beliefs preceded a change in instruction or vice versa" (p. 423). Some teachers' beliefs change before practice, and others change practice before their beliefs change (Philipp, 2007). Guskey (1986) describes a process in which teachers implement an instructional change, students succeed, and teacher beliefs change. Barkatas and Malone (2005) also found that teachers change their beliefs in light of classroom experience and when they see value in terms of student outcomes. Philipp (2007) suggests that exposure to mathematics teaching and learning practices may change teachers' beliefs and knowledge. In fact, teachers' beliefs and practices are likely to change when they learn about children's mathematical thinking.

Finding four: Enacted practices.

Teaching in a STEAM school influenced teachers' enacted practices in relation to situating mathematics in the real world. Teachers used students'

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names and timely and shared experiences when posing problems and emphasized the use of mathematics in the real world. In her final observation, Lillian used the names of first grade teachers and a timely and shared experience (composting) that was a part of the first grade spring STEAM unit. Tiffany and Rebecca also use real names in the problems that the presented to the students.

In the final interview, teachers emphasized the use of mathematics in the real world. While Stephanie revealed doubts in the initial interview about the influence that teaching in a STEAM school would have on mathematics teaching, her responses to similar questions in the final interview revealed the belief that real world problems should play a major role in mathematics teaching and learning.

She reflected:

I think math is so important whenever they're using it to solve real world problems. I think that's the whole idea behind STEAM. That they are taking their learning and trying to solve something larger and then they notice their impact on it. I think that's what's great about the STEAM school …We have the opportunity to have guest speakers that go along with our project and then it gave the kids a whole new appreciation for why we're learning math and why it's so important in how they're going to use it when they're adults and it makes it a little more relevant. I think it makes kids more passionate when they understand the reason they have to know something is because they're going to use it later on. It's not just

temporary knowledge…After we had that one speaker, I had a student that I was struggling to reach an interest with and he really thought it would be great to be a coastal engineer. He wrote in his journal about how he is going to work so hard in math because that's what he wants to be. I think it gave him a little more willpower to work hard and study and learn those facts just so that he could become what he wanted to be. That's kind of powerful.

Tiffany also emphasized the importance of connecting mathematics to the real world. In her final observation, she initiated a discussion about why it is important to measure precisely in the real world. She asked, "How could I use this in the real world? What's something that could cause major problems?" "Why would I be measuring this rug in the real world?" She then gave the students an opportunity to discuss the reasons why someone would have to measure the rug. Next, she encouraged the students to "Tell me something in your real life." One student said, "Medicine!" Tiffany probed, "Why?" Tiffany then facilitated a discussion about why it is important to measure medicine carefully.

These shifts in enacted practices offer promise for situating mathematics professional development in a STEAM school. Curriculum change is a complex process and it is evident that any successful reform will take into account teacher beliefs about the intended, the implemented, and the attained curriculum (Handal & Herrington, 2003). Philipp (2007) conjectured, "The most lasting change will result from professional development experiences that provide teachers with opportunities to coordinate incremental change in beliefs with corresponding

change in practice" (p. 281). Once mathematics teachers understand and believe in the reform, they will lead the way in ensuring its success (Goldin et al., 2009). As teachers in a STEAM school do their work of teaching they will have opportunities, by the nature of the setting, to experience incremental changes in their beliefs with corresponding changes in their enacted practices.

Implications for Practice

This study contributes to a better understanding of how being situated in a STEAM school influences teachers' enacted practices and beliefs about teaching and learning mathematics. The finding that teachers in a STEAM school hold reform-oriented beliefs about mathematics teaching and learning is encouraging given the current push for STEAM instructional practices. Additionally, the consistent finding that reform-oriented practices are attributed to teachers' levels of reflectiveness and interpretation/misinterpretation of instructional practices advocated by the reform movement has implications for teacher educators. Teaching in a STEAM school also strengthened teachers' beliefs about the importance of integration and connecting mathematics to authentic, real world situations. This strengthening in beliefs may be attributed to the positive influence the teachers perceive that these practices have on students and the establishment of a safe environment. Finally, teaching in a STEAM school influenced teachers' enacted practices in relation to situating mathematics in authentic, real world situations. As teachers in a STEAM school do their work of teaching, they will have opportunities, by the nature of the setting, to experience

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incremental changes in their beliefs with corresponding changes in their enacted practices.

Utilizing a STEAM Setting to Cultivate Reform-oriented Beliefs

"Teachers are those who ultimately decide the fate of any educational enterprise" (Handal & Herrington, 2003, p. 65). Therefore, in order for reform efforts to be successful, teachers must hold beliefs that are compatible with the innovation. Philipp (2007) conjectured, "the most lasting change will result from professional development experiences that provide teachers with opportunities to coordinate incremental change in beliefs with corresponding change in practice" (p. 281). Once mathematics teachers understand and believe in the reform, they will lead the way in ensuring its success (Goldin, et al., 2009).

One of the major challenges facing teacher educators and researchers is understanding how to create learning experiences powerful enough to transform teachers' classroom practice. Studies of learning demonstrate that the content of what is learned is often tied to the context in which it is learned (Henning, 2004). The situated perspective focuses on communities of practice which include individuals as participants who interact with each other as well as tools and representational systems (Greeno, 1997). The interactions within these communities of practice are major determinants of what is learned and how it is learned.

When applied to teacher learning, the situated perspective suggests that teacher learning should be grounded in some aspect of teacher practice. Much of

what teachers learn is situated within the context of classrooms and teaching (Carter, 1990; Carter & Doyle, 1989). Communities of practice are formed within these contexts and become the locus for teacher learning and play central roles in shaping what teachers learn and how they go about doing their work (Putnam & Borko, 2000).

The finding in this study that teachers in a STEAM setting hold similar and consistent beliefs that are productive in light of reform efforts suggests that this setting cultivates reform-oriented beliefs. Additionally, the strengthening in beliefs and practices in relation to integration and problem solving provides further evidence that the STEAM setting cultivates reform-oriented beliefs and practices. The problem-based nature of STEAM instructional approaches provides a context for learning, presents multiple lines of inquiry, and situates the learning in real world situations, which provide a setting for process skills such as creativity and collaboration. Authentic tasks tap students' interests by addressing real world, timely, and local issues. Inquiry rich experiences are driven by students' curiosity, wonder, interest, and passion and require students to find their own pathways through the problem. Additionally, student choice encourages multiple ways to solve a problem and provides opportunities for students to choose the path they take when solving the problem.

Given the mutual roles of STEAM and the reform movement of mathematics education, the recent emphasis on STEAM instructional approaches offers one vehicle for achieving the aims of the reform movement in mathematics education. Mathematics teacher educators can improve reform

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efforts by capitalizing on the current push for STEAM. Specifically, they may situate teacher learning within a STEAM setting. Situating teacher learning within a STEAM setting that prioritizes problem solving, authentic tasks, inquiry, process skills, student choice, and integration is one vehicle for achieving the goals of mathematics reform. Namely, the setting can be used to cultivate reform-oriented beliefs and, in time, reform-oriented practices. The STEAM school is an ideal setting for cultivating reform-oriented practices because of the mutual goals and the finding that teachers in a STEAM setting hold similar and consistent beliefs about mathematics teaching and learning that are considered productive in light of reform efforts. As the reform-oriented beliefs are strengthened through participation in the community of practice a safe environment for implementing reform-oriented practices is created. Specifically, the STEAM setting provides a safe environment for teachers who hold reform-oriented beliefs that have not yet translated into their instructional practices with opportunities to coordinate their beliefs with corresponding changes in practice.

Utilizing Teacher Reflection to Cultivate Reform-oriented Practices

Since beliefs serve as filters through which new ideas are perceived, it is essential for teachers to be challenged to reflect upon their beliefs. Teachers need systematic guidance in developing the skills for critical reflection and self-appraisal (Barkatsas & Malone, 2005).

The consistent finding that reform-oriented practices are attributed to teachers' levels of reflectiveness and interpretation/misinterpretation of instructional practices advocated by the reform movement also has implications

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for teacher educators. As with other settings, teacher learning within a STEAM setting must utilize reflection to cultivate reform-oriented practices. Phillip (2007) explains, "When practicing teachers have opportunities to reflect upon innovative reform-oriented curricula they are using, upon their own students' mathematical thinking, or upon other aspects of their practices, their beliefs and practices change" (p. 309).

Recommendations for Research

This case study provided a deeper understanding of the enacted practices and beliefs about mathematics teaching and learning held by elementary mathematics teachers situated in a STEAM school. This research is essential to filling the gap in current literature related to the influence that a STEAM setting has on teachers' beliefs about mathematics teaching and learning and the practices they enact. Given the infancy of STEAM and the limited research base, this research may be enhanced and extended in several important areas. First, conducting this study during the first year of a STEAM school provided a unique opportunity to investigate the influence of the setting on mathematics teachers' enacted practices and beliefs about mathematics teaching and learning. Extending this research beyond the first year would enable researchers to observe changes in practices and beliefs beyond the first year when the environment is more stable in terms of resources, procedures, policies, and relationships. Second, extending the research to additional grade levels may also enhance and extend the findings of this study. Third, a line of inquiry that investigates the effects of coupling the STEAM setting with a focus on reflective

practices is suggested. Finally, simultaneously studying the beliefs and practices of mathematics teachers situated in a STEAM school and the beliefs and practices of mathematics teachers in a control group would contribute to a better understanding of the influence teaching in a STEAM school has on teachers' beliefs about mathematics teaching and learning and the practices they enact.

Conclusion

In conclusion, this study provided information for teacher educators in the field of mathematics education to consider. This study contributes to a better understanding of how being situated in a STEAM school influences teachers' enacted practices and beliefs about teaching and learning mathematics. The finding that teachers in a STEAM school hold reform-oriented beliefs about mathematics teaching and learning is encouraging given the current push for STEAM instructional practices. Mathematics teacher educators can improve reform efforts by capitalizing on the current push for STEAM. Specifically, they may situate teacher learning within a STEAM setting. Additionally, the consistent finding that reform-oriented practices are attributed to teachers' levels of reflectiveness and interpretation/misinterpretation of instructional practices advocated by the reform movement has implications for teacher educators. Finally, the findings of this study may be enhanced and extended by continuing to investigate the enacted practices and beliefs about mathematics teaching and learning beyond the first year in a STEAM setting, extending the study to other grade levels, investigating the effects of coupling the STEAM setting with a focus on reflective practices, and simultaneously studying the beliefs and practices of

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mathematics teachers situated in a STEAM school and the beliefs and practices

of mathematics teachers in a control group.

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APPENDIX A – INVITATION TO PARTICIPATE

University of South Carolina

Elementary Math Teachers' Beliefs and Practices: Understanding the Impact of Teaching in a STEAM Setting

TEACHER INVITATION TO PARTICIPATE

You are invited to participate in a research study of how practicing in a STEAM context impacts your dispositions (perceptions, attitudes, and beliefs) and enacted classroom practices. I am not evaluating your teaching abilities nor testing student knowledge in any way. I will solely be investigating your dispositions and enacted practices, and how practicing in a STEAM context impacts them. I ask that you read this form and ask any questions you may have before agreeing to be in the study.

The study is being conducted by Melissa Negreiros, doctoral student at the University of South Carolina.

PROCEDURES FOR THE STUDY:

If you agree to be in the study:

1. I will ask you to complete a pre- and post-survey (one in September 2016 and one in January 2017) via Google forms.
2. I will interview and audio record you two times throughout the study (once in October 2016 and once in February 2017).
3. I will ask you to compile a modified Scoop Notebook during two 10-day "scoop" periods (once in September 2016 and once in January 2017).
4. I will observe an entire math lesson two times during the data collection period (once in October 2016 and once in January/February 2017).

RISKS OF TAKING PART IN THE STUDY

There are certain risks or discomforts that you might expect if you take part in this research. You may feel uncomfortable being recorded, interviewed, or observed. You can refuse to answer any question that makes you feel uncomfortable and can stop participation at any time.

BENEFITS OF TAKING PART IN THE STUDY

You may benefit from this study by reflecting on and discussing your perceptions, attitudes, and beliefs about teaching and learning math, which may help you in future teaching.

CONFIDENTIALITY

Efforts will be made to keep your personal information confidential. The school's and individuals' identities will remain strictly confidential. Interviews, surveys, observations, and Scoop Notebooks will be assigned a random ID number. The de-identified interview transcripts, completed de-identified surveys, de-identified Scoop Notebooks, and de-identified observation notes will be accessible only to the researcher of this study. Any presentations or published reports of this study will disclose only aggregate and/or de-identified results, and will not identify you in any manner. Audio recordings will be used for study purposes only and will be destroyed after 3 years' time of the study's completion.

VOLUNTARY NATURE OF STUDY

Taking part in this study is voluntary. You may choose to take part or may leave the study at any time. Leaving the study will not result in any penalty or loss of benefits to which you are entitled. Your decision whether or not to participate in this study will not affect your current or future relations with the investigator.

CONTACTS FOR QUESTIONS OR PROBLEMS

For questions about the study contact the researcher **Melissa Negreiros** at 843-460-0564 or negreirosm@bcsdschools.net. If you have any questions or concerns about your rights in this research study, please contact the University of South Carolina's Office of Research Compliance at 803-777-7095 or arlenem@mailbox.sc.edu.

SUBJECT'S CONSENT

In consideration of all of the above, I give my consent to participate in this research study. I will be given a copy of this informed consent document to keep for my records. I agree to take part in this study.

Subject's Printed Name:_____

Subject's Signature:_____
Date:_____

Printed Name of Person Obtaining Consent:_____

Signature of Person Obtaining Consent:_____
Date:_____

APPENDIX B – MECS-PRESTEAM

Mathematical Experiences and Conceptions Survey--preSTEAM

Form description

Thank you for agreeing to take the Mathematics Experiences and Conceptions *
Survey. Completion of the survey constitutes your consent to participate.

☐ I agree to participate in the survey.

☐ I do not agree to participate in the survey. If this is selected, then skip to the end of the survey.

Demographic Information

Description (optional)

Name *

Short answer text

How many years of teaching experience do you have? *

Short answer text

Gender

☐ Male

☐ Female

Please list your certification area(s). *

Short answer text

Please briefly describe your teaching experiences, including your experiences teaching math and/or STEAM. *

Long answer text

A. Using the scale below, respond to the following statements regarding your attitudes about mathematics.

Strongly Disagree (1) Disagree (2) Somewhat Disagree (3) Somewhat Agree (4) Agree (5) Strongly Disagree (6)

I like mathematics. (1) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Mathematics is one of my favorite subjects. (2) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I think mathematics is boring. (3) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I enjoy solving mathematics problems. (4) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I am anxious about teaching mathematics. (5) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I look forward to teaching mathematics. (6) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

B. Using the scale below, respond to the following statements regarding your beliefs about mathematics.

Strongly Disagree (1) Disagree (2) Somewhat Disagree (3) Somewhat Agree (4) Agree (5) Strongly Disagree (6)

There is typically one way to solve a mathematics problem. (1) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Doing mathematics involves analyzing multiple strategies for solving problems. (2) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

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Mastering facts and developing skills for carrying out calculations is essential * to knowing mathematics. (3)

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Mathematics is an attempt to know more about the world around us. (4) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Mathematics involves making generalizations. (5) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Mathematics is rarely used in society. (6) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Mathematics involves constructing an argument. (7) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Knowing mathematics is mostly about performing calculations. (8) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Mathematics is essential to everyday life. (9) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

C1. Using the scale below, respond to the following statements regarding your confidence in mathematics.

Strongly Disagree (1) Disagree (2) Somewhat Disagree (3) Somewhat Agree (4) Agree (5) Strongly Disagree (6)

I am confident in my ability to be a good mathematics teacher. (1) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I can figure out K-6 mathematics content with which I am unfamiliar. (2) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I am knowledgeable in mathematics. (3) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I am prepared to be a good mathematics teacher. (4) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

TE1. Using the scale below, respond to the following statements regarding your experiences with teaching math.

Strongly Disagree (1) Disagree (2) Somewhat Disagree (3) Somewhat Agree (4) Agree (5) Strongly Disagree (6)

Overall, my teaching experiences have provided me experiences with selecting * cognitively demanding mathematical tasks. (1)

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Overall, my teaching experiences have provided me experiences with fostering * a supportive learning environment. (2)

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Overall, my teaching experiences have provided me experiences with facilitating collaborative mathematical discourse. (3) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Overall, my teaching experiences have provided me experiences with using multiple representations of mathematical concepts and procedures. (4) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Overall, my teaching experiences have provided me experiences with using developmentally appropriate teaching strategies. (5) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

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Overall, my teaching experiences have provided me experiences with supporting all students' participation in the study of mathematics. (6) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Overall, my teaching experiences have provided me experiences with selecting and using instructional materials/resources to support the development of students' mathematical thinking. (7) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Overall, my teaching experiences have provided me experiences with using a variety of instructional strategies (e.g. direct instruction, inquiry-based instruction, group work) to support the development of students' mathematical thinking. (8) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Overall, my teaching experiences have provided me experiences with assessing students' understanding of mathematics. (9) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

TE2. Using the scale below, respond to the following statements regarding your experiences with teaching math.

Strongly Disagree (1) Disagree (2) Somewhat Disagree (3) Somewhat Agree (4) Agree (5) Strongly Disagree (6)

Overall, my teaching experiences have provided me experiences with using and managing manipulatives to teach mathematical concepts. (1) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Overall, my teaching experiences have provided me experiences with the South Carolina College- and Career-Ready Standards for Mathematics. (2) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Overall, my teaching experiences have provided me experiences with the
South Carolina College- and Career-Ready Mathematics Process Standards.
(3)

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Overall, my teaching experiences have provided me experiences with
connecting mathematics to students' lives outside the classroom. (4)

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Overall, my teaching experiences have provided me experiences with teaching
mathematics to high achievers. (5)

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Overall, my teaching experiences have provided me experiences with teaching *
mathematics to students who do not speak English as their primary language.
(6)

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Overall, my teaching experiences have provided me experiences with teaching *
mathematics to students with special needs. (7)

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Overall, my teaching experiences have provided me experiences with teaching *
mathematics to students of different ethnic/racial/cultural backgrounds. (8)

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

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Overall, my teaching experiences have provided me experiences with using technologies to enhance students' learning of mathematics. (9) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Overall, my teaching experiences have provided me experiences with differentiating instruction to meet students' needs in mathematics. (10) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Overall, my teaching experiences have provided me experiences with using cooperative groups to facilitate mathematics learning. (11) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

D1. Using the scale below, respond to the following statements regarding your mathematics instruction.

Strongly Disagree (1) Disagree (2) Somewhat Disagree (3) Somewhat Agree (4) Agree (5) Strongly Disagree (6)

I use hands-on materials (for e.g., blocks, cubes, spinners) to teach mathematics. (1) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I encourage students to solve mathematical problems in more than one way. (2) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I connect mathematics topics to students' lives outside the classroom. (3) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

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C2. Using the scale below, respond to the following statement below.

Strongly Disagree (1) Disagree (2) Somewhat Disagree (3) Somewhat Agree (4) Agree (5) Strongly Disagree (6)

My knowledge of mathematics is sufficient to teach. (1) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

D2. Using the scale below, respond to the following statements regarding your mathematics instruction.

Strongly Disagree (1) Disagree (2) Somewhat Disagree (3) Somewhat Agree (4) Agree (5) Strongly Disagree (6)

In engage students in mathematics discussions. (1) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I have student share their strategies in mathematics class. (2) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I lecture as my primary method of mathematics instruction. (3) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I encourage students to explain their thinking. (4) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I use cooperative group in mathematics instruction. (5) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I differentiate my mathematics instruction. (6) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

C3. Using the scale below, respond to the following statements.

Strongly Disagree (1) Disagree (2) Somewhat Disagree (3) Somewhat Agree (4) Agree (5) Strongly Disagree (6)

I teach mathematics effectively to high achievers. (1) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I teach mathematics effectively to students who do not have English as their primary language. (2) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I teach mathematics effectively to students with special needs. (3) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I teach mathematics effectively to students of different ethnic/racial/cultural backgrounds. (4) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

SJ1. Using the scale below, respond to the following statements regarding your beliefs and attitudes about mathematics.

Strongly Disagree (1) Disagree (2) Somewhat Disagree (3) Somewhat Agree (4) Agree (5) Strongly Disagree (6)

Social justice plays an important role in the teaching and learning of mathematics. (1) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Every student can be successful at learning mathematics. (2) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Mathematics can help students critically analyze the world. (3) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Issues about equity should be addressed in the mathematics classroom. (4) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

All students should be held to high expectations in mathematics. (5) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I integrate issues of social justice in my mathematics instruction. (6) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

SJ2. Using the scale below, respond to the following statements regarding your beliefs and attitudes about mathematics.

Strongly Disagree (1) Disagree (2) Somewhat Disagree (3) Somewhat Agree (4) Agree (5) Strongly Disagree (6)

Mathematics is a culturally neutral subject. (1) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

It is reasonable to have lower expectations in mathematics for students with special needs. (2) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

It is important to use students' cultural knowledge when teaching mathematics. (3) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Whether students succeed in mathematics depends primarily on how hard they work. (4) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Mathematics instruction does not need to be differentiated for ELLs because mathematics is a universal language. (5) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

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C4. Using the scale below, respond to the following statements.

Strongly Disagree (1) Disagree (2) Somewhat Disagree (3) Somewhat Agree (4) Agree (5) Strongly Disagree (6)

I am prepared to teach students effectively in an urban setting. (1) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I am prepared to teach students effectively in a suburban setting. (2) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I am prepared to teach students effectively in a rural setting. (3) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

TE3. Please answer the following questions in regards to your previous experiences teaching mathematics.

Strongly Disagree (1) Disagree (2) Somewhat Disagree (3) Somewhat Agree (4) Agree (5) Strongly Disagree (6)

Generally, I have had positive teaching experiences. (1) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Disagree

My teacher colleagues contributed greatly to my knowledge about the teaching and learning of mathematics. (2) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Disagree

My teaching experiences have generally reinforced what I learned in my mathematics methods course(s). (3)

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Disagree

My teacher colleagues used hands-on materials (for e.g., blocks, cubes, spinners) to teach mathematics. (4)

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Disagree

My teacher colleagues used lectures as their primary method of mathematics instruction. (5)

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Disagree

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Teaching Experiences

Description (optional)

FE4. Grade level(s) of teaching experience(s). (Check all that apply.) *

- ☐ Kindergarten (1)
- ☐ First Grade (2)
- ☐ Second Grade (3)
- ☐ Third Grade (4)
- ☐ Fourth Grade (5)
- ☐ Fifth Grade (6)
- ☐ Sixth Grade (7)
- ☐ Seventh Grade (8)
- ☐ Eighth Grade (9)
- ☐ Ninth Grade (10)
- ☐ Tenth Grade (11)
- ☐ Eleventh Grade (12)
- ☐ Twelfth Grade (13)

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FE4b. What math course(s) did you teach? *

Short answer text

FE5. Please select the setting(s) for your teaching experiences. (Check all that * **apply.)**

☐ Urban (1)

☐ Suburban (2)

☐ Public (3)

☐ Charter (4)

☐ Private (religious) (5)

☐ Private (non-religious) (6)

☐ Public (religious) (7)

What math curriculum is used by your school? *

Short answer text

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FT. Using the scale below, respond to the following statements.

Strongly Disagree (1) Disagree (2) Somewhat Disagree (3) Somewhat Agree (4) Agree (5) Strongly Disagree (6)

My past K-5 school experiences have a major impact on the way I teach mathematics. (1) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

My past 6-8 school experiences have a major impact on the way I teach mathematics. (2) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

My past 9-12 school experiences have a major impact on the way I teach mathematics. (3) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Mathematics content course(s) have a major impact on the way I teach mathematics. (4) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Math methods course(s) have a major impact on the way I teach mathematics. (5) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Field experiences prior to internship/student teaching have a major impact on *
the way I teach mathematics. (6)

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Internship/student teaching experiences have a major impact on the way I *
teach mathematics. (7)

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

My experiences teaching have a major impact on the way I teach *
mathematics. (8)

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

APPENDIX C – MECS-STEAM

Section 1 of 16

Mathematical Experiences and Conceptions Survey--STEAM

Form description

Thank you for agreeing to take the Mathematics Experiences and Conceptions *
Survey. Completion of the survey constitutes your consent to participate.

- [ ] I agree to participate in the survey.

- [ ] I do not agree to participate in the survey. If this is selected, then skip to the end of the survey.

Name *

Short answer text

Highest Degree Earned *

- ( ) Bachelor's Degree

- ( ) Master's Degree

- ( ) Specialist Degree or Doctorate Degree

Please list degrees earned. *

Long answer text

A. Using the scale below, respond to the following statements regarding your attitudes about mathematics.

Strongly Disagree (1) Disagree (2) Somewhat Disagree (3) Somewhat Agree (4) Agree (5) Strongly Disagree (6)

I like mathematics. (1) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Mathematics is one of my favorite subjects. (2) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I think mathematics is boring. (3) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I enjoy solving mathematics problems. (4) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I am anxious about teaching mathematics. (5) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I look forward to teaching mathematics. (6) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

B. Using the scale below, respond to the following statements regarding your beliefs about mathematics.

Strongly Disagree (1) Disagree (2) Somewhat Disagree (3) Somewhat Agree (4) Agree (5) Strongly Disagree (6)

There is typically one way to solve a mathematics problem. (1) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Doing mathematics involves analyzing multiple strategies for solving problems. (2) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

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Mastering facts and developing skills for carrying out calculations is essential * to knowing mathematics. (3)

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Mathematics is an attempt to know more about the world around us. (4) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Mathematics involves making generalizations. (5) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Mathematics is rarely used in society. (6) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Mathematics involves constructing an argument. (7) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Knowing mathematics is mostly about performing calculations. (8) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Mathematics is essential to everyday life. (9) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

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C1. Using the scale below, respond to the following statements regarding your confidence in mathematics.

Strongly Disagree (1) Disagree (2) Somewhat Disagree (3) Somewhat Agree (4) Agree (5) Strongly Disagree (6)

I am confident in my ability to be a good mathematics teacher. (1) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I can figure out K-6 mathematics content with which I am unfamiliar. (2) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I am knowledgeable in mathematics. (3) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I am prepared to be a good mathematics teacher. (4) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

TE1. Using the scale below, respond to the following statements regarding your experiences with teaching math in a STEAM setting.

Strongly Disagree (1) Disagree (2) Somewhat Disagree (3) Somewhat Agree (4) Agree (5) Strongly Disagree (6)

My STEAM teaching experiences have provided me experiences with selecting * cognitively demanding mathematical tasks. (1)

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

My STEAM teaching experiences have provided me experiences with fostering * a supportive learning environment. (2)

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

My STEAM teaching experiences have provided me experiences with facilitating collaborative mathematical discourse. (3) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

My STEAM teaching experiences have provided me experiences with using multiple representations of mathematical concepts and procedures. (4) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Overall, my teaching experiences have provided me experiences with using developmentally appropriate teaching strategies. (5) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

My STEAM teaching experiences have provided me experiences with supporting all students' participation in the study of mathematics. (6) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

My STEAM teaching experiences have provided me experiences with selecting * and using instructional materials/resources to support the development of students' mathematical thinking. (7)

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

My STEAM teaching experiences have provided me experiences with using a * variety of instructional strategies (e.g. direct instruction, inquiry-based instruction, group work) to support the development of students' mathematical thinking. (8)

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

My STEAM teaching experiences have provided me experiences with assessing students' understanding of mathematics. (9) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

TE2. Using the scale below, respond to the following statements regarding your experiences with teaching math in a STEAM setting.

Strongly Disagree (1) Disagree (2) Somewhat Disagree (3) Somewhat Agree (4) Agree (5) Strongly Disagree (6)

My STEAM teaching experiences have provided me experiences with using and managing manipulatives to teach mathematical concepts. (1) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

My STEAM teaching experiences have provided me experiences with the South Carolina College- and Career-Ready Standards for Mathematics. (2) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

My STEAM teaching experiences have provided me experiences with the
South Carolina College- and Career-Ready Mathematics Process Standards.
(3) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

My STEAM teaching experiences have provided me experiences with
connecting mathematics to students' lives outside the classroom. (4) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

My STEAM teaching experiences have provided me experiences with teaching *
mathematics to high achievers. (5)

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

My STEAM teaching experiences have provided me experiences with teaching *
mathematics to students who do not speak English as their primary language.
(6)

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

My STEAM teaching experiences have provided me experiences with teaching *
mathematics to students with special needs. (7)

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

My STEAM teaching experiences have provided me experiences with teaching *
mathematics to students of different ethnic/racial/cultural backgrounds. (8)

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

My STEAM teaching experiences have provided me experiences with using *
technologies to enhance students' learning of mathematics. (9)

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

My STEAM teaching experiences have provided me experiences with differentiating instruction to meet students' needs in mathematics. (10) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

My STEAM teaching experiences have provided me experiences with using cooperative groups to facilitate mathematics learning. (11) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

D1. Using the scale below, respond to the following statements regarding your mathematics instruction.

Strongly Disagree (1) Disagree (2) Somewhat Disagree (3) Somewhat Agree (4) Agree (5) Strongly Disagree (6)

I use hands-on materials (for e.g., blocks, cubes, spinners) to teach mathematics. (1) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I encourage students to solve mathematical problems in more than one way. (2) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I connect mathematics topics to students' lives outside the classroom. (3) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

C2. Using the scale below, respond to the following statement below.

Strongly Disagree (1) Disagree (2) Somewhat Disagree (3) Somewhat Agree (4) Agree (5) Strongly Disagree (6)

My knowledge of mathematics is sufficient to teach. (1) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

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D2. Using the scale below, respond to the following statements regarding your mathematics instruction.

Strongly Disagree (1) Disagree (2) Somewhat Disagree (3) Somewhat Agree (4) Agree (5) Strongly Disagree (6)

In engage students in mathematics discussions. (1) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I have students share their strategies in mathematics class. (2) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I lecture as my primary method of mathematics instruction. (3) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I encourage students to explain their thinking. (4) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I use cooperative group in mathematics instruction. (5) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I differentiate my mathematics instruction. (6) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

C3. Using the scale below, respond to the following statements.

Strongly Disagree (1) Disagree (2) Somewhat Disagree (3) Somewhat Agree (4) Agree (5) Strongly Disagree (6)

I teach mathematics effectively to high achievers. (1) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I teach mathematics effectively to students who do not have English as their primary language. (2) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I teach mathematics effectively to students with special needs. (3) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I teach mathematics effectively to students of different ethnic/racial/cultural backgrounds. (4) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

SJ1. Using the scale below, respond to the following statements regarding your beliefs and attitudes about mathematics.

Strongly Disagree (1) Disagree (2) Somewhat Disagree (3) Somewhat Agree (4) Agree (5) Strongly Disagree (6)

Social justice plays an important role in the teaching and learning of mathematics. (1) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Every student can be successful at learning mathematics. (2) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Mathematics can help students critically analyze the world. (3) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Issues about equity should be addressed in the mathematics classroom. (4) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

All students should be held to high expectations in mathematics. (5) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I integrate issues of social justice in my mathematics instruction. (6) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

SJ2. Using the scale below, respond to the following statements regarding your beliefs and attitudes about mathematics.

Strongly Disagree (1) Disagree (2) Somewhat Disagree (3) Somewhat Agree (4) Agree (5) Strongly Disagree (6)

Mathematics is a culturally neutral subject. (1) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

It is reasonable to have lower expectations in mathematics for students with special needs. (2) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

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It is important to use students' cultural knowledge when teaching mathematics. (3) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Whether students succeed in mathematics depends primarily on how hard they work. (4) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Mathematics instruction does not need to be differentiated for ELLs because mathematics is a universal language. (5) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

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C4. Using the scale below, respond to the following statements.

Strongly Disagree (1) Disagree (2) Somewhat Disagree (3) Somewhat Agree (4) Agree (5) Strongly Disagree (6)

I am prepared to teach students effectively in an urban setting. (1) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I am prepared to teach students effectively in a suburban setting. (2) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

I am prepared to teach students effectively in a rural setting. (3) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

TE3. Please answer the following questions in regards to your experiences teaching mathematics in a STEAM setting.

Strongly Disagree (1) Disagree (2) Somewhat Disagree (3) Somewhat Agree (4) Agree (5) Strongly Disagree (6)

The STEAM setting cultivates positive mathematics teaching experiences. *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Disagree

My teacher colleagues in the STEAM setting contribute greatly to my knowledge about the teaching and learning of mathematics. (2) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Disagree

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My teaching experiences in the STEAM setting have generally reinforced what *
I have learned in my previous teaching experiences.

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Disagree

My teacher colleagues in the STEAM setting use hands-on materials (for e.g., *
blocks, cubes, spinners) to teach mathematics. (4)

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Disagree

My teacher colleagues in the STEAM setting use lectures as their primary *
method of mathematics instruction. (5)

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Disagree

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Teaching Experiences

Description (optional)

FE4. Grade level(s) of teaching experience(s). (Check all that apply.) *

- [ ] Kindergarten (1)
- [ ] First Grade (2)
- [ ] Second Grade (3)
- [ ] Third Grade (4)
- [ ] Fourth Grade (5)
- [ ] Fifth Grade (6)
- [ ] Sixth Grade (7)
- [ ] Seventh Grade (8)
- [ ] Eighth Grade (9)
- [ ] Ninth Grade (10)

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☐ Tenth Grade (11)

☐ Eleventh Grade (12)

☐ Twelfth Grade (13)

FE4b. What math course(s) did you teach? *

Short answer text

FE5. Please select the setting(s) for your teaching experiences. (Check all that * apply.)

☐ Urban (1)

☐ Suburban (2)

☐ Public (3)

☐ Charter (4)

☐ Private (religious) (5)

☐ Private (non-religious) (6)

☐ Public (religious) (7)

What math curriculum is used by your school? *

Short answer text

FT. Using the scale below, respond to the following statements.

Strongly Disagree (1) Disagree (2) Somewhat Disagree (3) Somewhat Agree (4) Agree (5) Strongly Disagree (6)

My past K-5 school experiences have a major impact on the way I teach mathematics. (1) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

My past 6-8 school experiences have a major impact on the way I teach mathematics. (2) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

My past 9-12 school experiences have a major impact on the way I teach mathematics. (3) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Mathematics content course(s) have a major impact on the way I teach mathematics. (4) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Math methods course(s) have a major impact on the way I teach mathematics. (5) *

	1	2	3	4	5	6	
Strongly Disagree	○	○	○	○	○	○	Strongly Agree

Field experiences prior to internship/student teaching have a major impact on *
the way I teach mathematics. (6)

	1	2	3	4	5	6	
Strongly Disagree	◯	◯	◯	◯	◯	◯	Strongly Agree

Internship/student teaching experiences have a major impact on the way I *
teach mathematics. (7)

	1	2	3	4	5	6	
Strongly Disagree	◯	◯	◯	◯	◯	◯	Strongly Agree

My experiences teaching have a major impact on the way I teach *
mathematics. (8)

	1	2	3	4	5	6	
Strongly Disagree	◯	◯	◯	◯	◯	◯	Strongly Agree

APPENDIX D – RTOP FIELD NOTES

Name of Teacher:
Grade Level:
Date of Observation:
Start Time:
End Time:

II. Contextual Background and Activities

In the space provided below please give a brief description of the lesson observed, the classroom setting in which the lesson took place (space, seating arrangements, etc.), and any relevant details about the students (number, gender, ethnicity) and teacher that you think are important. Use diagrams if they seem appropriate.

Time	Description of Events

If something is observed, it must at least be rated 1.
III. Lesson Design and Implementation

1. The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein. (*refers back to prior learning-at least a 1; lesson set-up to build on students' prior understanding--4*)

2. The lesson was designed to engage students as members of a learning community.(*completely teacher-centered-0, no evidence of community-0, community, but instructor presents answer/solution-3; 4 must include student-to-student construction of ideas and understanding*)

3. In this lesson, student exploration preceded formal presentation.

4. This lesson encouraged students to seek and value alternative modes of investigation or of problem solving. (*instructed how/specific strategy--low score*)

5. The focus and direction of the lesson was often determined by ideas originating with students.(*teacher set agenda--low score*)

IV. Content

6. The lesson involved fundamental concepts of the subject.

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7. The lesson promoted strongly coherent conceptual understanding. (*only logical progression-1, group discussion-high*)

8. The teacher had a solid grasp of the subject matter content inherent in the lesson. (*no factual errors-4*)

9. Elements of abstraction (i.e., symbolic representations, theory building) were encouraged when it was important to do so. (*use of drawings, props, concrete examples--high, ideas student developed--high*)

10. Connections with other content disciplines and/or real world phenomena were explored and valued. (*real world AND relevance to everyday life--4*)

Procedural Knowledge

11. Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena. (*articulated final ideas--high, students must represent in multiple ways for a 4*)

12.Students made predictions, estimations and/or hypotheses and devised means for testing them. (*score of 0 if students do not make and text predictions, estimates, etc*)

13. Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures. (*students entirely passive--0, students perform critical assessment--high*)

14. Students were reflective about their learning. (*silence insufficient--0, questions such as How do we know this? How can we be sure? What does this tell us about what we know?--high, evidence of ALL students thinking about their thinking--4*)

15. Intellectual rigor, constructive criticism, and the challenging of ideas were valued. (*competing ideas offered--high score*)

V. Classroom Culture

Communicative Interactions

16. Students were involved in the communication of their ideas to others using a variety of means and media.(*communication implies negotiation of meaning--not simply ask and respond; whole class discussion and group to group negotiations--4*)

17. The teacher's questions triggered divergent modes of thinking.(*asking divergent questions to the whole class AND groups of students--4, 2 if divergent questions are asked, but it is clear that the teacher is looking for a specific answer*)

18. There was a high proportion of student talk and a significant amount of it occurred between and among students.(*answering questions not scored, even talk--2*)

19. Student questions and comments often determined the focus and direction of classroom discourse.

20. There was a climate of respect for what others had to say.(*to receive a 4 must involve sharing to the whole class; score drops if teacher closes down student exploration*)

Student/Teacher Relationships

21. Active participation of students was encouraged and valued.(*answering questions at least 1; to receive a 4 students must play a major role in constructing and validating the final explanation to the whole class*)

22. Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence.(*must be discussed as a whole class to receive a 4, only 1 path-- 1*)

23. In general the teacher was patient with students.(*wait time at least 1, missed opportunities lowers scores*)

24. The teacher acted as a resource person, working to support and enhance student investigations. (*students provided with ample opportunities to explore on their own terms--4; teacher answering questions instead of directing inquiry lowers score*)

25. The metaphor "teacher as listener" was very characteristic of this classroom.(*4-- teacher listens and does not dominate the conversation; teacher too directive lowers score*)

Additional comments you may wish to make about this lesson.

APPENDIX E – RTOP

I. Background Information

Form description

Teacher Name

Short answer text

Announced Observation?

☐ Yes

☐ No

Location of class (district, school, room)

Short answer text

Years of Teaching

Short answer text

Teaching Certification

☐ K-8

☐ 7-12

Subject observed

Short answer text

Grade level

☐ Kindergarten

☐ First

☐ Second

☐ Third

☐ Fourth

Observer

Short answer text

Date of Observation

Short answer text

Start time

Short answer text

End time

Short answer text

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II. Contextual Background and Activities

Description (optional)

In the space provided below please give a brief description of the lesson observed, the classroom setting in which the lesson took place (space, seating arrangements, etc.), and any relevant details about the students (number, gender, ethnicity) and teacher that you think are important. Use diagrams if they seem appropriate. Include time and description of events.

Long answer text

III. Lesson Design and Implementation

Description (optional)

The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein.

	0	1	2	3	4	
Never Occurred	○	○	○	○	○	Very Descriptive

The lesson was designed to engage students as members of a learning community.

	0	1	2	3	4	
Never Occurred	○	○	○	○	○	Very Descriptive

In this lesson, student exploration preceded formal presentation.

	0	1	2	3	4	
Never Occurred	○	○	○	○	○	Very Descriptive

This lesson encouraged students to seek and value alternative models of investigation or of problem solving.

	0	1	2	3	4	
Never Occurred	○	○	○	○	○	Very Descriptive

The focus and direction of the lesson was often determined by ideas originating with students.

	0	1	2	3	4	
Never Occurred	○	○	○	○	○	Very Descriptive

IV. Content--Propositional knowledge

Description (optional)

The lesson involved fundamental concepts of the subject. *

	1	2	3	4	
Never Occurred	○	○	○	○	Very Descriptive

The lesson promoted strongly coherent conceptual understanding.

	0	1	2	3	4	
Never Occurred	○	○	○	○	○	Very Descriptive

The teacher had a solid grasp of the subject matter content inherent in the lesson.

	0	1	2	3	4	
Never Occurred	○	○	○	○	○	Very Descriptive

Elements of abstraction (i.e., symbolic representations, theory building) were encouraged when it was important to do so.

	0	1	2	3	4	
Never Occurred	○	○	○	○	○	Very Descriptive

Connections with other content disciplines and/or real world phenomena were explored and valued.

	0	1	2	3	4	
Never Occurred	○	○	○	○	○	Very Descriptive

IV. Content--Procedural knowledge

Description (optional)

Students used a variety of means (models, drawings, graphs, concrete materials, manipulatives, etc.) to represent phenomena.

	0	1	2	3	4	
Never Occurred	○	○	○	○	○	Very Descriptive

Students made predictions, estimates and/or hypotheses and devised means for testing them.

	0	1	2	3	4	
Never Occurred	○	○	○	○	○	Very Descriptive

Students were actively engaged in thought-provoking activity that often involved the critical assessment of procedures.

	0	1	2	3	4	
Never Occurred	○	○	○	○	○	Very Descriptive

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Students were reflective about their learning.

	0	1	2	3	4	
Never Occurred	○	○	○	○	○	Very Descriptive

Intellectual rigor, constructive criticism, and the challenging of ideas were valued.

	0	1	2	3	4	
Never Occurred	○	○	○	○	○	Very Descriptive

V. Classroom Culture--Communicative Interactions

Description (optional)

Students were involved in the communication of their ideas to others using a variety of means and media.

	0	1	2	3	4	
Never Occurred	○	○	○	○	○	Very Descriptive

The teacher's questions triggered divergent modes of thinking.

	0	1	2	3	4	
Never Occurred	○	○	○	○	○	Very Descriptive

There was a high proportion of student talk and a significant amount of it occurred between and among students.

	0	1	2	3	4	
Never Occurred	○	○	○	○	○	Very Descriptive

Student questions and comments often determined the focus and direction of classroom discourse.

	0	1	2	3	4	
Never Occurred	○	○	○	○	○	Very Descriptive

There was a climate of respect for what others had to say.

	0	1	2	3	4	
Never Occurred	○	○	○	○	○	Very Descriptive

V. Classroom Culture--Student/Teacher Relationships

Description (optional)

Active participation of students was encouraged and valued.

	0	1	2	3	4	
Never Occurred	○	○	○	○	○	Very Descriptive

Students were encouraged to generate conjectures, alternative solution strategies, and ways of interpreting evidence.

	0	1	2	3	4	
Never Occurred	○	○	○	○	○	Very Descriptive

In general the teacher was patient with students.

	0	1	2	3	4	
Never Occurred	○	○	○	○	○	Very Descriptive

The teacher acted as a resource person, working to support and enhance student investigations.

	0	1	2	3	4	
Never Occurred	○	○	○	○	○	Very Descriptive

The metaphor "teacher as listener" was very characteristic of this classroom.

	0	1	2	3	4	
Never Occurred	○	○	○	○	○	Very Descriptive

Section 8 of 8

Additional comments you may wish to make about this lesson.

Description (optional)