USING THE CONTEXTUALIZED INTERACTION MODEL TO EXAMINE CHANGES IN TEACHER BELIEFS

by

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ABSTRACT

HENRY WHITEHEAD NEALE, JUNIOR. Using the contextualized interaction model to examine changes in teacher beliefs. (Under the direction of DR. DAVID PUGALEE)

With the increased importance placed on the science, technology, engineering, and mathematics (STEM) fields throughout the world but particularly in the United States, research in mathematics education has become widely recognized as critical to efforts to improve the ability of U. S. students to compete in a global market. A key focus of this movement has included efforts to improve the teaching of mathematics. Unfortunately, changes in teachers' practices have been slow to evolve. Researchers have found that teachers' beliefs are a critical barrier to enacting change. Though the relationship between teacher beliefs and practices has been studied since the early 80's, a consistent and encompassing model for the interaction between teachers' beliefs and practices has not emerged. This paper presents a proposed model of teacher change, the *Contextualized Interaction Model,* and the findings of a multiple case study which utilized the model to examine the changes in the beliefs of three elementary teachers engaged in a professional development program. The proposed model was found to accurately include the various factors which appear to interact with teacher beliefs though it was altered to include the impact of the curriculum as a key factor. The various contextual factors represented by the proposed model were found to profoundly impact the alignment between teachers' beliefs and practices.

ACKNOWLEDGEMENTS

My metaphor for completed a doctoral degree has been running a marathon. The years prior to conducting the dissertation study are much like the months of intensive and directed training a runner must endure just to prepare to run a full marathon. During this training phase, all runners learn a great deal about their specific running styles, bad habits, etc. They also learn a great deal about themselves. The marathon itself of course is the culmination of all that effort; the singular target on which they've focused their efforts for months. And the goal during this marathon? Get the darn thing finished as quickly as possible. As is the case with the best runners, an entire team is required to help them train and complete the marathon. Without the support, expertise, and motivation provided by the right team, I highly doubt that any marathon, even Marathon's run itself, would have ever been completed. I imagine that Marathon would never have pushed himself at all if he hadn't been focusing on the lives of his friends, family, and countrymen. And though I have not died in my effort, I confess that my contributions to this dissertation are less significant than the combined contributions of my teammates. I must therefore appropriately acknowledge the motivation, support, and expertise provided by my friends, family, and countrymen.

Obviously, the faculty and staff at The University of North Carolina have provided the requisite expertise. Though I have undoubtedly been bettered by all of the interactions I've had with the faculty and staff, there are several individuals who have made specific contributions of which I am particularly appreciative. I must credit Dr. Greg Wiggan for putting me on the path to becoming a decent writer. He helped me learn how to consistently improve my writing. Dr. Richard Lambert and Dr. Flowers gave me a strong background in statistics. Dr. Lim guided me toward being able to conduct strong qualitative research. It’s also important that I acknowledge the financial contributions and other support provided by Charlotte Country Day School. I greatly enjoyed working there and would not have been able to afford the time required to complete this program or the financial burden without the school’s aggressive support for the continued education of their staff.

I would like to devote a paragraph to thank my dissertation committee. They were an absolutely wonderful group of professionals with which to work. Dr. Jane Gaultney participated on the dissertation committee as the university’s representative. I greatly appreciated her useful feedback on my proposal while also going out of her way to provide some positive feedback during the proposal meeting when she felt I needed it. Dr. Vic Cifarelli has been my advisor since I began my masters courses at UNCC in 1994. I have learned mathematics, mathematics education, and how to conduct qualitative research from Dr. Cifarelli. Dr. Cifarelli and Dr. Jeong-Lim Chae led the course during which I first began conceiving of this dissertation paper. They both also helped guide the literature review. They also both helped guide my understanding of mathematics education. One course I took with Dr. Chae in particular led me to solidify my views regarding strong instruction and strong math education research. Dr. Drew Polly didn’t join UNCC until I had already started the proposal process. I’ve known him for less than two years, but in that short time, his expertise and knowledge have proven to be an invaluable resource. I have no doubt that I will continue to rely heavily on Dr. Polly as a resource throughout my career.

It seemed necessary to separate my acknowledgement of Dr. David Pugalee. I first met Dr. Pugalee when I interviewed to enroll in the Curriculum and Instruction Doctoral program. For several years since I had finished my masters in 2001, I had been pushing for UNCC to create a doctoral program in math education, but there didn't seem to be enough support for it. I was so excited when the C&I program came up. I was immediately impressed by the questions Dr. Pugalee asked during the interview. I could tell he liked my answers, but I could also tell that he was pushing me to deepen my, at the time, very shallow understanding of the issues facing mathematics education. I had no idea how significantly Dr. Pugalee would help shape my career. Dr. Pugalee has provided incredibly helpful advice on every significant career decision I've made since meeting him a decade ago. I would not be as strong a teacher, researcher, or educational leader without his guidance. He's been a like my own personal career counselor and benefactor and has played an indirect and sometimes very direct role in all the positive career moves that have evolved for me since I started the program. I only hope that I am able to continue to work with him in the future, though I know my debt to him will never be paid.

Lastly, I must thank my wife, Dr. Melia Neale. If Dr. Pugalee has been my guide, my wife has been my motivation, energy, drive, and support. Even with the best guidance, experience, and knowledge, no one is able to accomplish anything of value without the time, opportunity, energy, and motivation to do it well. My wife provided for all those things. I owe her for literally tens of thousands of hours watching our daughters, Makena and Maggie; throughout the eight years it's taken me to complete this program. I owe her for the tens of thousands of dollars it's cost us to complete this program. I owe her for the tens of thousands of problems she's helped me solve as I've progressed through the program. I owe her for the tens of thousands of words of encouragement she provided throughout the last decade. But most importantly, my lovely wife is responsible for the last decade being a taste of heaven instead of hell. I can understand how some students progress through a program like this and feel like they've gone through hell. To the outside observer, it would seem as if I dragged this process out for eight years. So many people have asked me how glad I'm going to be to have it finally done. I suppose that, without my wife, I would be desperate to finish this journey. But, because of my wife, I've wanted this trip to last as long as possible. I'm in no hurry to get done because of her. Because of her, I know the next journey will be just as wonderful. She makes the greatest challenges pleasant for me. It's nice to be done, but because of her, the entire process has been enjoyable for me. And because of her, all things will remain joyful for me.

Thank you all.

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CHAPTER 1: INTRODUCTION

As John Dewey (1916) intoned almost a full century ago, schools exist to expedite the socialization process previously achieved through a child's normal upbringing. By the 19th century, no child could possibly acquire a proper knowledge base to function successfully without the aid of a formalized educational system. As we've moved into the 21st century, the need for an efficient educational system has increased significantly. As Dewey predicted, researchers have demonstrated causal links between low academic achievement and societal problems (e.g. National Science Board, 1999. Today children are growing up in a society permeated by mathematics (National Research Council, 2001; Moses & Cobb, 2001; National Council of Teachers of Mathematics, 2000; Papert, 1993). Technologies used in homes, businesses, and schools are built on mathematical knowledge, and many careers demand high levels of mathematics (National Research Council, 2001). Unfortunately, especially in the United States, we have yet to develop an educational system that evolves along with society. This failure is felt most poignantly in the areas of mathematics and science; the very areas that are so crucial to the future of America which have also been the focus of educational reform since the late 50's.

Mathematics Reform Efforts in the United States

International assessments like the *Trends in Mathematics and Science Studies* (*TIMSS*) and the *Programme for International Student Assessment* (*PISA*) have indicated that the U.S. mathematics program has consistently lagged behind many other industrialized countries such as Japan, China, Singapore, and the Netherlands (Tobergte & Curtis, 2002; Valverde & Schmidt, 2000; U. S. Department of Education, 2000). The typical American eighth grader has tested well behind his peers in other advanced countries (e.g. Tobergte & Curtis, 2002; Valverde & Schmidt, 2000). In 2001, The National Research Council (NRC) announced that U.S. students were especially deficient in the competencies required to understand mathematics deeply and use it effectively. Some researchers felt that the lack of clear progress on international assessments revealed that mathematics reform efforts lacked the necessary focus, coherence, intensity, and scale (e.g. Ferrini-Mundy, 2004). U.S. students also seemed to have negative beliefs and attitudes toward mathematics as well. The 1986 *National Assessment of Education Progress*, Brown et al (1988) found that 50% of American students believed that learning mathematics meant memorizing. Schoenfeld (1988) found that, in light of typical instructional practices, it was not surprising that most students believed that math included isolated topics unrelated to the real world. In 2004, Muis concluded that U.S. students at all levels of schooling consistently held unavailing beliefs and attitudes toward mathematics. And Freeman (2004) found that students' positive feelings toward mathematics had dropped over the previous decade. Researchers have also found a direct relationship between teacher beliefs and student achievement (Fennema, Carpenter, Franke, Levi, Jacobs, & Empson, 1996; Philipp, 2007; Staub & Stern, 2002). Students' unavailing beliefs and attitudes appear to reflect those of teachers; teachers who may lack the knowledge required to alter those beliefs and attitudes.

Several studies have demonstrated that teachers' mathematical knowledge is critical for effective instruction (e.g. Hill, Rowan, & Ball, 2005), but most elementary and secondary school teachers in the U.S. lack a conceptual understanding of the mathematics they're supposed to be teaching (Ball, Hill, & Bass, 2005; Mewborn, 2002). Many elementary teachers have only a procedural understanding of mathematics (Da Ponte & Chapman, 2006) which helps explain why the average U.S. student is taught specific procedures and content well, but not how to think mathematically (Birenbaum, Tatsuoka, & Xin, 2005). U. S. teachers have had a consistent and predictable way of teaching mathematics (Hiebert, 1999). One key characteristic of this traditional approach is the emphasis on teaching procedures, especially computation procedures which can make it more difficult for students to go back and gain a conceptual understanding of the material later (Brownell & Chazal, 1935; Mack, 1990; Resnick & Omanson, 1987; Wearne & Hiebert, 1988). And though the vast majority of teachers report that they are aware of current educational reforms (Stein, 2004; U. S. Department of Education, 2003; Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003; California State University, 1997), these teachers' practices rarely reflect the standards recommended by national mathematics educational organizations (Hiebert & Stigler, 2000; Stigler & Hiebert, 1999; U. S. Department of Education, 2003). Additionally, the U.S. curriculum, when compared to other industrialized countries, has tended to provide few opportunities for students to solve challenging problems and to engage in mathematical reasoning, communicating, conjecturing, justifying, and proving (Hiebert, 1999). If the United States hopes to start making forward progress with its mathematics program, significant changes are required, and teachers play the most important role in changing the way students learn mathematics (Dana & Yendol-Silva, 2003; Darling-Hammond, 1998; Meyer, 2005). The NRC (2001) defined the learning goal of insuring that all students obtain mathematical proficiency based on five strands: 1) Conceptual understanding, 2) Procedural fluency, 3) Strategic competence, 4) Adaptive reasoning, and 5) Productive disposition (NRC, 2001). Most recently, the Council of Chief State School Officers and the National Governors Association Center for Best Practices (2010) released their Common Core for Mathematics which was expressly designed to help improve mathematics instruction in the United States in order to equip students to compete globally. But the relevant data indicate that most teachers are poorly equipped to meet the demands of teaching toward this goal (Da Ponte & Chapman, 2006). These reviews, reports, international assessments, and research studies indicate the desperate need to improve mathematics instruction in the United States. Unfortunately, the typical U.S. mathematics student experiences a weak curriculum which is frequently taught using deficient methods by teachers who have unavailing beliefs about mathematics and lack the strong understanding of mathematics required for teaching. The U.S. mathematics program will not show significant improvement until the beliefs and practices of U.S. mathematics teachers improve. Educational researchers and policy makers believe that professional development is the best vehicle for addressing this issue.

Professional Development in the United States

Educational researchers (e.g. Borko, 2004; Darling-Hammond & Skyes, 1999; Garet, Porter, Desimone, Briman, & Yoon, 2001; Guskey, 1991, 2002; Leung, Yung, & Tso, 2005; Polly & Hannafin, 2011; Yoon, Duncan, Lee, Scarloss, & Shapley, 2007) and organizations (National Partnership for Educational Accountability in Teaching [NPEAT], 2000a, 2000b; National Staff Development Council [NSDC], 2002) have consistently stressed the critical role that professional development must play in reforming mathematics education. The U. S. Commission on National Security (2001) stated that there was no threat to U.S. national security as great as that posed by the inadequacies of the current system of education and research. The NRC (2007) made several recommendations to avoid this imminent educational collapse, one of which focused on vastly improving K-12 Education in the U.S. by strengthening current teachers through funded training and education. But professional development in the United States has consistently failed to impact teachers' instructional practices.

After a decade of post-Sputnik mathematics reform focused on "beefing up the subject matter was matched with a strong concern for inquiry, discovery, and problem solving, for student-initiated activities and divergent thinking (Shulman, 1986), *A Nation at Risk* (National Committee on Excellence in Education [Excellence Committee], 1983) documented the failure of post-Sputnik reform efforts to close the gap in math and science achievement between the United States and other industrialized nations. The Conference Board of the Mathematical Sciences (1975) found that "Teachers are essentially teaching the same way they were taught in school" (p. 77). Two decades and multiple national and local reform efforts later, the average classroom in the United States has revealed the same methods of teaching mathematics today that have been in place for nearly a century (Dixon et al., 1998, Fey, 1979; Knapp, 1997; Speilman & Lloyd, 2004; Steele, 2001; Stigler & Hiebert, 1999; Welch, 1978). These traditional yet ineffective methods have persisted even in the face of pressure to change. At the turn of the century, researchers reiterated the consistent ineffectiveness of most professional development programs (e.g. Cohen & Hill, 1998; Kennedy, 1998; Wang, Frechtling, & Sanders, 1999). Many professional development practices in the U.S. are not supported by research and others are outright contradicted by research findings (Guskey, 2003). The failure of professional development efforts in the United States is particularly disturbing because professional development programs in some of the countries that outperform the U.S. are quite different (e.g. Jacobs & Morita, 2002). One key reason why professional development has failed to impact teachers' practices is because it has failed to impact teacher beliefs.

U.S. teachers need to shift their beliefs about mathematics, teaching and learning (Darling-Hammond & Sykes, 1999; Smith, 2001). The need to alter teachers' beliefs is particularly important because teacher beliefs appear to interact with so many important student outcomes. The relationship between teacher beliefs and teacher practices has been well established (Cooney & Brown, 1982; Leder, Pehkonen, & Torner, 2002; Pajares 1992; Philipp, 2007; Wilkins, 2008). Researchers have recognized the impact that a teacher's beliefs toward mathematics, learning, and teaching can have on various aspects of teacher practice: curriculum planning and implementation (Collopy, 2003; Remillard & Bryans, 2004), instructional decisions (Franke, Fennema, & Carpenter, 1997; Leder, Pehkonen, & Torner, 2002), use of technology (Walen, Williams, & Garner, 2003; Philipp, 2007), reflection (Thompson, 1984; Breyfogle, 2005), and participation in professional development (Johnson, 2006). And though researchers have been investigating teacher beliefs for two decades, professional development efforts in the United States have continued to remain ineffective.

The tendency of reform efforts to only influence instruction in marginal or peripheral ways has been well-documented (see Hiebert & Stigler, 2000; Meyer, 2005). This failure to genuinely impact instructional practices is partly due to teachers' tendency to transform curricular materials to fit into their pre-existing beliefs systems. An overwhelming majority of American teachers believe they have implemented reform ideas into their classrooms (Stein, 2004; U.S. Department of Education, 2003; Loucks-Horsley et al., 2003; California State University, 1997). But when theses teachers were observed, the overwhelming majority had implemented only peripheral changes; their underlying teaching philosophies were unchanged (U.S. Department of Education, 2003; Stigler & Hiebert, 1999). Teachers described organizational alterations instead of core changes in instruction (Hiebert, & Stigler, 2000). Hiebert & Stigler also found that U.S. teachers, more so than German or Japanese teachers, tended to believe that they were aware of reform ideas and that their teaching reflected these ideas. However, both German and Japanese teachers' lessons better reflected reform efforts than U.S. lessons. Professional development is unlikely to result in changes in teachers' practices if teachers perceive no need to make changes. An awareness of the need to change appears to be lacking among U.S. teachers. This motivation to change reflects a cultural component of professional development which is usually implemented in a non-cultural fashion (Hiebert & Stigler, 2000). Teacher training frequently occurs outside the classroom (Sarason, 1983; Guskey, 2003), and curricular and pedagogical decisions are made, not by the teachers directly affected by these decisions, but by individuals who are out of contact with implementation (Sarason, 1997). Teachers are required to allocate limited time and resources while attempting to balance increasing and conflicting demands (Education Trust, 2002).

Purpose of Study

Significance of the Study

Educators and administrators have struggled for decades to determine the types of professional development activities that lead to changes in teachers' practices (Breyfogle, 2005). Adding to this dilemma is the lack of theory regarding how teachers learn reform-based practices (Wilson & Ball, 1996) and the assertion from researchers that many teachers will need to alter their beliefs toward mathematics and mathematics instruction (Darling-Hammond & Skyes, 1999; Smith, 2001). The U.S. mathematics program needs effective professional development, but there are multiple components to this effort that are missing; the most important of which is an accurate model of teacher change around which successful professional development can be designed. Professional development in the United States has continued to be based on a psychotherapeutic model of teacher change (Guskey, 2002). But professional development based on this model of teacher change has been ineffective.

Examining teacher beliefs has become a very popular area of research over the last two decades, and the significance of research into teacher beliefs is becoming increasingly important (Philipp, 2007). Multiple researchers have noted the complexity involved in efforts to impact teacher beliefs (e.g. Guskey, 1991; Fullan, 1982; Wilkins, 2008). And despite extensive research, no consistent patterns have emerged from these investigations (Leder, Pehkonen, & Torner, 2002). Some researchers (e.g. Bencze & Hodson, 1999; Reed, 2002) believe that teachers must view lessons as experiments to become generative professionals (see Leung, Yung, & Tso, 2005). Hiebert, Morris, & Glass (2003) worked with pre-service teachers to instill this experimental view toward teaching and to develop the knowledge and skills required for teachers to design lesson and reflect on lesson successfulness by focusing on student thinking. In 2006, Da Ponte and Chapman (2006) indicated the need for "a global theory" (p. 471) relating teacher knowledge, beliefs, and practice. And Philipp (2007) recently concluded that researchers are still trying to understand the relationship between teacher knowledge, beliefs, and affect and teacher practices. Philipp also highlighted the need for researchers to negotiate between constructivist and sociocultural views. Finally, Philipp charged researchers with the challenge of determining how to change teacher beliefs.

Professional development has been identified as a key factor in improving American mathematics education (NRC, 2007). But professional development has consistently failed to impact teacher beliefs which are a key factor in improving teacher practice and ultimately student outcomes. Researchers have confirmed that the relationship between beliefs and practice is more cyclical than linear (Guskey, 2002; Breyfogle, 2005). With this model of changing beliefs in mind, researchers (e.g. Breyfogle, 2005; Guskey, 2003; Leung, Yung, & Tso, 2005; Philipp, 2007) have pushed for professional development which focuses on the interaction between beliefs and practices. Researchers have called for professional development to be embedded into the work of teaching instead of relying on out of context workshops (Ball & Cohen, 1999; Breyfogle, 2005; Loucks-Horsley, Hewson, Love, & Stiles, 1998; Schifter & Fosnot, 1993; Smith, 2001; Sykes & Darling-Hammond, 1999). Research over the last several decades has clearly demonstrated that the typical model of professional development simply does not work. This same research supports alternative models for teacher change. However researchers have yet to create an accurate model of teacher change which accounts for competing perspectives and inconsistencies between beliefs and practices. Until researchers can develop a complete model for teacher change and demonstrate the accuracy of this model, developing effective professional develop will remain challenging. The U. S. mathematics program cannot afford to continue as it has over the last half century. Finding a model for teacher change that explains and predicts changes in teacher beliefs and determining the teacher views that allow teachers to engage and test their beliefs are critical to this endeavor. The purpose of this study was to propose a new, encompassing model for teacher change, the *Contextualized Interaction Model*, to utilize this model to examine changes in teacher beliefs, and to examine the degree to which having an experimental view toward teaching accounts for changes in teacher beliefs.

Research questions

There were two overarching research questions:

Research Question #1: In what ways does the Contextualized Interaction Model help examine changes in the beliefs of teachers engaged in a professional development program?

Research Question #2: To what extent does having an experimental view toward teaching account for changes in beliefs?

Based on the assumptions that the *Contextualized Interaction Model* was valid and that an experimental view toward teaching could explain changes in teacher beliefs, several other research questions were investigated:

- In what ways do teachers’ beliefs about mathematics, teaching, and learning change?
    - Do the *CI* model and an experimental view account for these changes?

- To what extent do teachers:
  - Perceive a need to try new instructional practices?
  - Plan lessons in order to try new instructional practices?
  - Try or 'test' different practices?
    - How do these practices differ from teachers' typical practices?
    - To what degree do these practices challenge or reinforce teacher beliefs?
  - Reflect on the effectiveness of different practices?
  - Utilize student thinking to measure lesson effectiveness?
  - Alter instructional practices based on this reflection?
- In what ways does a teacher's knowledge interact with a teacher's beliefs and practices?

The literature review will begin with a discussion of key terms followed by a thorough review of mathematics education research focused on teacher beliefs. The Theoretical Framework will include a historical review of models of teacher change followed by a description of the proposed *Contextualized Interaction Model of Teacher Change*. The methodology will describe the participants, instruments used in the study, and the gathering of data and will include a detailed account of the analysis of the data. The Findings from the study will then be presented followed by the Conclusion which will include the limitations, implications, and a thorough discussion section.

CHAPTER 2: LITERATURE REVIEW

A Historical Contextualization of Beliefs Research

Reform Induced by Sputnik

The creation of the atomic bomb and its use to end World War II established the United States as a world leader. Americans believed that our educational system was moving along well (Seeley, 2009). This view of world domination persisted until Russia's successful launch of the satellite Sputnik forced Americans to question the status of the domination of the U.S. mathematics and science programs. Sputnik launched a cyclic wave of reform efforts and educational research in mathematics, science, and technology which has continued into the 21st century. The initial wave of reform was termed the *new math*. This initiative focused on discovery, divergent and creative thinking, and was based on Bloom's Taxonomy (Shulman, 1986). Though the ideals of this reform effort may have been well conceived, researchers, educators, and curriculum designers had yet to gain a strong understanding of the requirements for successful implementation. The *new math* reform effort of the 60's failed to permeate the American culture and resulted in the *back to basics* reform effort of the 1970's. This reform effort was more comfortable for teachers and parents because it was focused on the procedures and arithmetic computation with which many parents and teachers were more familiar (e. g. Seeley, 2009).

Post-Sputnik reform efforts also launched the establishment of educational assessments. The *National Assessment of Education Progress* (NAEP) was established in 1964 with the first assessment occurring in 1969 (National Center for Educational Statistics, 2009). NAEP data has been used ever since to help measure national educational progress and direct initiatives. In the 60's and 70's, educational research was in its infancy. Appropriate research practices had yet to be established. Researchers relied on convenient measures that were easily quantifiable. Poor instruments which lacked validity testing were used to measure student achievement, and weak but convenient measures, like number of math courses taken, were used to indicate teacher knowledge (e. g. Mewborn, 2002). The relationships between these poor measures of student achievement and teacher characteristics were subsequently weak and inconsistent. Researchers in the 60's and 70's concluded that socio-economic status (SES) and familial background were the only variables that correlated strongly with student achievement (Coleman, 1966). Teacher characteristic variables were subsequently dismissed as good predictors of achievement (e.g. Begle, 1979).

However, educators and researchers recognized the need to improve measures of teaching. In the 70's and 80's, researchers began to investigate other indicators and to conduct qualitative and mixed method studies in addition to the typical quantitative approaches (Suter, 2000). Using alternate measures, researchers added to their findings on SES. Factors like 'opportunity to learn' were found to correlate with achievement (Comber & Keeves, 1973; Peak, 1975). In 1975, Coleman's re-analysis of the data from his 1966 study found that reading comprehension correlated far more strongly with SES and familial background than other content areas. These findings continued to drive researchers to find more consistent and valid measures of teaching and student achievement. A critical question that grew from this research era was if teaching actually impacted student achievement.

The 80's also brought clear indicators of the failure of post-Sputnik reform efforts. The qualitative and mixed methods studies describing and determining teachers' mathematical knowledge found that many teachers knew math facts and algorithms but lacked a conceptual understanding of the mathematics they were supposed to be teaching (Mewborn, 2002; Ball, Hill, & Bass, 2005). The National Committee on Excellence in Education presented its 1983 report: *A Nation at Risk*. This Excellence Commission revealed that national efforts to close the achievement gap between the U.S. and other industrialized countries had failed (e.g. Hofmeister, 2003). Any gains made during the *new math* initiative instigated by Sputnik had been squandered by the *back to basics* approach (Seeley, 2009). One positive result of post-Sputnik reform efforts was that researchers, instead of focusing on teacher characteristics, began to focus more on what teachers actually did in the classroom (Ball, 1991). Researchers began to investigate teachers' notions of effective teaching (Wilkins, 2008). Work in the field of cognitive science drove interest into teacher beliefs (Furinghetti & Pehkonen, 2002).

Modern Era Reform Efforts

International comparisons. The failure of post-Sputnik reform efforts led to renewed national efforts. Mathematics education organizations, like the *National Council of Teachers of Mathematics* (NCTM), were created with the specific goal of improving mathematics instruction. In 1989, NCTM released its landmark document *Curriculum and Evaluation Standards for School Mathematics*. NCTM produced this document to help guide teachers by indicating what students needed to know and be able to do throughout the educational program (Seeley, 2009). The NCTM would later release its *Principles and Standards for School Mathematics* in 2000 to provide further guidance and direction for educators.

In an attempt to demonstrate that teaching impacts student achievement, researchers began examining international educational practices. Educational systems throughout the world hoped to learn how to improve mathematics and science instruction by learning from each other. For the United States, these studies represented a repetition of the Sputnik defeat. The TIMSS data from 1995 and 1999 revealed a traditional U.S. curriculum that was relatively repetitive, unfocused, and undemanding (Schmidt, McKnight, & Raizen, 1996; Silver, 1998). Cogan and Schmidt (1999) coined the description of the U.S. mathematics curriculum as “a mile wide and an inch deep” which was marked by low level and low quality content and questions (Stigler, Gallimore, & Hiebert, 2000). The endeavor to develop the US mathematics curriculum has continued to maintain the focus of educational researchers as well as politicians. These endeavors have led to the most recent initiative; the Common Core. The *Common Core State Standards Initiative* was undertaken to address the issue that “the mathematics curriculum in the United States must become substantially more focused and coherent in order to improve mathematics achievement in this country” (p. 3, CSSO and the NGA Center, 2010). The *Common Core State Standards for Mathematics* includes content standards along with Standards for Mathematical Practice which describes “varieties of expertise that mathematics educators at all levels should seek to develop in their students” (p. 6). The content standards were aimed at more clearly, accurately, and concisely identifying the mathematics content that K-12 students in the U. S. should be learning while the mathematics practices were aimed at addressing the instructional issues facing the nation's mathematics program. This newest document clearly described the endeavor to improve both curricula and instruction.

The results of educational initiatives, national curricula, and cultural trends throughout various nations revealed strong cultural components, even national ideologies, in the teaching of mathematics and science in different countries (Schmidt et al, 1996). Schmidt et al further concluded that, compared to other countries, "U.S. educators appear to prolong childhood by extending exposure to more basic science and mathematics topics into lower secondary school" (p. 132). Researchers found that U. S. mathematics teachers had a very consistent and predictable way of teaching which provided few opportunities for students to solve challenging problems and to engage in mathematical reasoning, communication, conjecture, justification, and proof (Hiebert, 1999). Birenbaum, Tatsuoka, & Xin (2005) asserted that the average U.S. student is taught specific procedures and content well, but not how to think mathematically. Teachers in the U.S. believed that they were teaching toward *The Standards* but in fact failed to do so (Hiebert & Stigler, 2000). To many, the findings from international comparisons indicated that the traditional curriculum and instructional methods in the United States were failing to serve students well (e.g. Hiebert, 1999; Suter, 2000).

In addition to variations in curriculum and instruction, international cultural factors appeared to influence multiple components of teaching. Teacher salaries and the respect accorded teachers appeared to be higher in countries which outperformed the U. S. For example, Singaporean teachers were found to receive higher pay, had a stronger background in mathematics, and engaged in more extensive professional development activities than U. S. teachers (Birenbaum, Tatsuoka, & Xin, 2005). Professional development in the U. S. was not implemented in a consistent fashion, but in Japan and other eastern countries that have historically outperformed the U. S., models for professional development were not only utilized consistently but also differed significantly from the typical U. S. model (Jacobs & Morita, 2002). In addition to differences in professional development, the tasks with which U. S. teachers have usually been charged appeared to be dramatically different then the work asked of teachers in other countries (LeTendre, Baker, Akiba, Goesling, & Wiseman, 2001). LeTendre et al. observed that U. S. teachers struggled to simply complete all the tasks required of them each day. They also found that, in striking contrast to the beliefs typically held by U. S. teachers (see Muis, 2004), Japanese teachers refuted beliefs in innate ability and tracking while also viewing student differences as instructionally advantageous. These findings have become alarming in light of research relating higher achievement to feelings of appreciation for teachers' work and decreased teacher time spent on administrative tasks (Leung, Yung, & Tso, 2005). Belief in the innateness of mathematical ability has been shown to relate to lower achievement (Muis, 2004). And perhaps even more disconcerting is the strong link which researchers have found between a country's economy and achievement (Birenbaum, Tatsuoka, & Xin, 2005); a link which U. S. performance has consistently contradicted.

Though discouraging for the U. S., the results of these international comparisons did provide mathematics educators with hope as the debate concerning school impact was resolved. Suter (2000) found that 45% of the variance in the 1999 TIMSS data was attributable to school or class characteristics as opposed to SES or familial background. Schmidt, McKnight, & Raizen (1998) found that curricular focal points impact student achievement. Hiebert (1999) summarized the findings from the international comparison studies by concluding that the "data confirm one of the most reliable findings from research on teaching and learning: Students learn what they have an opportunity to learn." (p. 12).

Teacher knowledge. In the 1960's and 1970's, early and sometimes unreliable research was conducted trying to identify relationships between teacher knowledge and student achievement (Mewborn, 2002). The measures of 'teacher knowledge' and 'student achievement' used were poor indicators, and the research conducted was based mostly on data that was easily accessible. Mewborn summarized that most of this research indicated no relationship between teacher knowledge and student achievement. In the 70's and 80's, research began to focus on determining what teachers knew (Mewborn, 2002). The picture of the average mathematics teacher painted by researchers was dark and grim. Teachers seemed to know math facts and algorithms but lacked a conceptual understanding of mathematics (Ball, 1990). This finding was particularly disturbing as mathematics reformers and educators were starting to recognize the desperate need for students to obtain a conceptual understanding of mathematics. Teachers lacking a conceptual understanding of mathematics are ill-equipped to facilitate student acquisition of a conceptual understanding (Ball, Hill, & Bass, 2005). Altering the curricular materials and providing detailed, fool-proofed lesson plans had consistently failed to compensate for teachers' weak understanding. And perhaps most alarmingly, the bleak description of teachers' knowledge of the mathematics required for teaching painted in the 80’s and again in the 90’s appears to be just as accurate today (e.g. Ball, Hill, & Bass, 2005).

To contradict the idea that “Those who can, do. Those who can't, teach”, Elbaz, Schon, and Shulman helped define and drive research into teacher knowledge. Elbaz (1983) focused on what teachers know that others do not. Schon (1983) identified reflecting-in-practice as a requirement of the teaching profession. Schon indicated that, as opposed to simply knowing things, teachers have to adjust to changing situations and possess knowledge with which they can appropriately act. Shulman (1986a) identified seven types of knowledge required for teaching: content, pedagogy, curriculum, pedagogical content knowledge, knowledge of students, knowledge of educational contexts, and knowledge of educational ends, purposes, and values. Shulman (1986b) went on to counter Shaw’s jibe by stating that “those who can do. Those who understand, teach.” (pg. 14)

Over the last two decades, researchers have refined their understanding of teacher knowledge. A particular advancement in this area is an improved determination of what counts as teacher knowledge. In the 60’s and 70’s, teacher knowledge focused almost strictly on pure subject matter content. In the 80’s and 90’s, the concept of teacher knowledge was broadened and more clearly defined by the work of researchers like Elbaz, Shulman, and Schon. Educators and researchers recognized that the breadth of knowledge someone needs to teach goes well beyond the knowledge required to do math problems. Support for Dewey’s (1916) argument that teaching math requires more than just knowing math was found through qualitative and quantitative research which revealed that knowing more mathematics did not appear to help someone teach mathematics better (Mewborn, 2002). Mewborn showed that knowledge of the subject matter, learners, learning theory, teaching strategies, and social context are critical for teaching.

While the knowledge base teachers need was being broadened beyond just subject matter, other researchers were increasing the specificity and depth of knowledge required to teach. Researchers and educators discussed ideas like inter-disciplinary content knowledge, curricular knowledge, and student error analysis. Additionally, educators and researchers have determined that the strongest teachers have a robust and rich understanding of basic mathematics in addition to understanding more advanced mathematics. To improve teaching, teachers need not learn more mathematics, but rather, understand the math they currently teach at a much deeper level. Ma (1999) determined that no U.S. teachers participating in her study possessed the profound understanding of mathematics that several Chinese teachers with extensive experience possessed. It's this profound understanding of what is considered basic mathematics that seems to be a key to improving teacher practices. Researchers utilizing a broader and deeper understanding of what constitutes teacher knowledge have found that teacher knowledge and teaching practices do relate to gains in achievement (Ball, 2004; Hill, Rowan, & Ball, 2005; Mewborn, 2002).

In addition to refining what teachers need to know, researchers also began to investigate other factors that impact teaching practices. One important result of the research in this area was the understanding that the relationship between teacher practice and teacher knowledge is very complex and depends on many different factors (Mewborn, 2002). Researchers have revealed that studies trying to relate teacher knowledge to student achievement in the past were woefully inadequate due to the complexity and multifaceted nature of the relationship between teacher knowledge and practice.

Since the distinction between content knowledge, pedagogical knowledge, and the knowledge required for teaching became salient, researchers have revisited the relationship between teacher knowledge and student achievement. Some researchers have verified the assumption that improving teacher knowledge leads to improved student achievement (Hill, Rowan, & Ball, 2005). But this research depends mostly on properly measuring teacher knowledge. Notably, Hill, Rowan, and Ball have developed an instrument for measuring teachers' mathematical knowledge for teaching and have demonstrated that high teaching knowledge results in greater gains in student achievement. The instrument used assessed teacher knowledge in various ways: ability to use mathematical language, ability to properly analyze student errors, find alternate solutions, inquire appropriately, develop representations, create contextually pertinent examples, and other factors. Though the researchers involved in trying to measure teacher knowledge recognize that much more work is needed, the current progress is reassuring. The only overarching conclusion of research into the relationship between teacher knowledge and teacher practices has been that more research is needed to determine which factors impact teaching practices, the degree to which they do so, and why these factors impact practices.

Teacher practice. In the late 80's and early 90's, researchers tried to understand why so many U. S. teachers were using teacher-centered, procedural instructional strategies in the classroom. A central focus for these researchers was trying to understand how teacher beliefs influenced teacher practice. Researchers like Nespor (1987), Pajares (1992), Thompson (1984, 1992), and Richardson (1996) found that teachers' beliefs greatly influence teacher practices. After a decade of research demonstrating the impact that beliefs can have on teacher practice, researchers went on to demonstrate that these beliefs towards mathematics and mathematics instruction impact teacher effectiveness as well (Earnest, 1989; Leder, Pehkonen, & Torner, 2002; Wilkins, 2008). Researchers also found that when teachers had a conceptual understanding of mathematics, classroom instruction was positively impacted (Fennema & Franke, 1992).

Researchers have also found that teacher practices are not always consistent with their beliefs but that beliefs provide the foundation for teachers' instructional decision making (Cooney 1985; Raymond 1997; Swan, in press; Thompson 1992, 1984). Subsequently, researchers have recognized the importance of examining teacher practices within the context of beliefs and content knowledge (e.g. Wilkins, 2008). In one of the few large scale quantitative studies investigating the relationship between beliefs, knowledge, and practices, Wilkins (2008) found that the beliefs of elementary teachers had a stronger relationship with practice than teacher knowledge or attitude. In addition to recognizing the impact that beliefs have on instruction and teacher effectiveness, researchers have also demonstrated the potential for professional development to impact teacher knowledge, beliefs, and practices.

The Emergence of Beliefs Research

At the beginning of the 20th century, beliefs and beliefs systems were considered focal topics for education (Leder, Pehkonen, & Torner, 2002; Thompson, 1992). However, the psychological theory of behaviorism pushed beliefs into the shadows until cognitive science provided a framework from which beliefs research could re-emerge in the 70's (Abelson, 1979). Beliefs ultimately grew into a central topic in educational research during the 80's due to efforts to reform education and the simultaneous push to investigate teacher beliefs from both psychological and sociological perspectives. During the 70s and 80s, research focused on the relationship between student achievement and teacher behaviors became prolific (Brophy & Good, 1986). There was a convergence of studies demonstrating the academic effects of teacher management, instructional strategies, and opportunity to learn (Turner & Meyer, 2000). The goal of these studies was to determine the teacher characteristics or behaviors that were correlated with achievement gains and then to follow up with experimental studies to see if these relationships were causal (Turner & Meyer, 2000). Accompanying this surge of psychological studies was a drive in sociology to investigate classroom interaction and classroom climate (Turner & Meyer, 2000). Starting in the early 70's and continuing into the 80's, cognitive science helped drive a shift in educational research from a focus on teacher behaviors to a focus on understanding teacher thinking and decision-making (Thompson, 1992).

In the early 80's researchers began to investigate teacher learning along with student learning (Da Ponte & Chapman, 2006). Researchers (e.g. Schoenfeld, 1985; Silver, 1985) had found that student beliefs played a crucial role in students' problem solving abilities, and that students' beliefs toward mathematics limited students' problem solving abilities. Posner, Strike, Hewson, & Gertzog, (1982) found that students accommodated new information in multiple ways to avoid conflict with their exiting beliefs. Pajares (1992) argued for the importance of studying beliefs because of the ways in which beliefs impact learning. Researchers have continued to study student beliefs due to the impact student beliefs can have on student achievement (e. g. Schinck, Neale, Pugalee, & Cifarreli, 2008). Research on student beliefs encouraged researchers to consider the impact that beliefs might have on teachers' knowledge and practice.

Early Beliefs Research

Research on beliefs was initially carried out from a psychological perspective (Llinares & Krainer, 2006; Richardson, 1996). Some of the earliest work on teacher beliefs focused on changing conceptions. Thompson (1992) reported that the work of Collier (1972) and Shirk (1973) led to the conclusion that significant changes in pre-service teachers' beliefs did not occur quickly. However, Thompson also noted that Meyerson (1978) was able to quickly and significantly alter the conceptions of teachers who were willing to doubt and reexamine their beliefs. Other early contributors include Fennema's investigations into gender related differences, the role of beliefs in mathematics, and the impact on achievement. Fennema contributed to several studies during the 80's including longitudinal studies which began in the early 70's. Fennema and Peterson (1985) concluded that societal factors could influence students' internal motivational beliefs. In the 70's and 80's, Thompson investigated the factors which constrain teacher performance (McLeod & McLeod, 2002). Thompson (1984) worked with three middle school mathematics teachers and found that reflecting on practice created opportunities for the teachers to confront and reconcile inconsistencies between their beliefs and practices. This ground-breaking work revealed the importance of studying beliefs as teachers attempt to adopt reform-based practices. Thompson showed that beliefs, along with teacher knowledge, play an important role in changing teacher performance.

In 1989, Carpenter and Fennema developed Cognitively Guided Instruction (CGI) to assist teachers engaged in in-service training. Carpenter and Fennema believed that teachers could learn to alter their practices if they focused on attending to student thinking. CGI was designed to help teachers focus their attention on understanding how students are thinking and utilize those observations to impact instruction. Carpenter and Fennema (1989) found that some teachers engaged in CGI demonstrated improved teacher knowledge, beliefs, and practices but that these changes were inconsistent and slow to develop. Carpenter, Fennema, Peterson, Chiang, & Loef (1989) began testing this theory toward teacher education which has continued to maintain the interest of educational researchers. They found that the practices and beliefs of several of their participants changed considerably as a result of the participants learning about student thinking (Thompson, 1992). Later, Franke, Carpenter, Levi, and Fennema (2001) conducted follow-up research on participants from the 1989 study. They found that teachers engaged in CGI continued to develop professionally over time.

Schoenfeld helped develop researchers' understanding of beliefs and how they relate to learning. Schoenfeld (1985) argued that cognitive behaviors take place within a social-cognitive framework and that beliefs provide the psychological context for learning. The cognitions that guide behavior are driven by beliefs about the task at hand, the social environment, and the individual's perceived relation to the task and the environment (Schoenfeld, 1983). Schoenfeld conducted ground-breaking work in his studies of students' mathematical beliefs. He identified several prevalent beliefs which hindered students’ mathematical achievement. Students tended to believe that teachers and textbooks are the authorities and dispensers of mathematical knowledge, and students readily accepted that knowledge without challenge (Schoenfeld, 1985). Schoenfeld (1988) found that most students believed the following: mathematics has nothing to do with discovery or invention, only geniuses are capable of really understanding mathematics, students who understand mathematics can solve assigned problems within 5 minutes, and to succeed in math, students need to perform tasks, to the letter, as described by the teacher. Schoenfeld went on to show that the learning environment may have fostered these beliefs. Since the primary goal of instruction was to prepare students to do well on the state exams, teachers focused on having students passively receive the directions required to complete the assigned exercises. Students practiced routine procedures and were required to execute them quickly. Students were never asked to engage in discovery or invention and were assigned exercises, not problems, designed to require less than 2 minutes each. Schoenfeld (1989) also found that students with higher grades were less likely to believe that mathematics was mostly memorization of teacher directed procedures.

Several other key contributors to this initial surge in beliefs research appeared in the late 80’s and early 90’s. Ernest was one key initiator of the movement toward research on teacher beliefs (Da Ponte & Chapman, 2006). As a natural progression of his investigation into teacher affect, Ernest (1989, 1991a) confirmed his assertion that teachers’ attitude towards and beliefs about mathematics impacted instructional decisions. Ernest extended this research by building a model to delineate teachers’ views toward mathematics to include views toward learning and teaching mathematics. Ernest also indicated that teachers tended to view mathematics from a problem solving, Platonist, or instrumentalist view. Mathematics tended to be viewed as an expanding field created by humans to solve problems, a static but interconnected body of knowledge discovered by humans, or as a set of unrelated utilitarian rules and facts (Thompson, 1992). This categorization of teacher views has continued to provide a foundation for theory building, data collection, and data analysis (e.g. Swan, 2004; Wilkins, 2008). Pajares was another initial investigator into beliefs. In 1992, Pajares posited that beliefs have to change in order for practice to change. This assertion has since been supported by substantial research (Philipp, 2007) but has also led to a common debate regarding the nature of the relationship between changes in beliefs and practices.

Attempts to understand the influence of professional development programs led to research focused on identifying changes in teacher beliefs (Llinares & Krainer, 2006). For example, in 1992, Tobin and Jakubowski proposed a schema of six cognitive requisites for enacting teacher change: (a) perturbation or uneasiness with the way things are; (b) awareness that improvement requires change; (c) commitment to move into action; (d) vision of teaching; (e) visualization of the changes in the classroom and reflection as they are taking place; and (f) reflection on teachers' own practices and raising questions about their own actions in the classroom. Tobin and Jakubowski's schema for change, Ernest's views towards mathematics, and Pajares linear progression provide excellent examples of researchers' early efforts to create models for understanding beliefs and enacting change. Efforts to model teacher change will be discussed at length in the theoretical framework.

These early efforts to model change along with the work of Schoenfeld, Fennema, and Thompson represent the key contributions which established beliefs as a critical factor in teacher change and an area of emphasis in educational research. An important result from this initial surge of research on beliefs, knowledge, and practice was the recognition that the relationship between the three was complicated and multifaceted and was influenced by many factors (Guskey, 1991, 2002; Fullan, 1982; Huberman & Miles, 1984; Mewborn, 2002). It was quickly evident that more research utilizing various and perhaps new methods and models would be needed. The interest generated by these studies and the obvious importance of teacher beliefs in achieving reform led to the first synthesis of beliefs research in 1992.

Thompson's Research Synthesis.

The first synthesis of the research on beliefs appeared in the first edition of the *Handbook of Research on Mathematics Teaching and Learning* in 1992. Thompson included conceptions along with beliefs in her synthesis which was indicative of the confusion over terminology. The lack of agreed upon definitions for and differentiation between beliefs, conceptions, values, knowledge, belief systems, cognitive constructs has continued to be problematic for researchers (e.g. Philipp, 2007). However, it is unlikely that agreement upon these definitions will ever exist. But even in this first synthesis, Thompson asserted that, rather than focusing on differentiating between knowledge and beliefs, researchers should focus on studying the interaction between affect, beliefs/knowledge and practice. This call for more research focused on the interaction between beliefs and practice reflected Thompson's view of beliefs as dynamic and subject to change based on experience. Thompson supported the dialectic relationship between beliefs and practices, and utilized Ernest's (1989, 1991a) model of teacher beliefs toward mathematics, teaching, and learning to indicate the important role that beliefs play in instruction. Thompson revealed some of the difficulties facing educational reform efforts to impact teacher practice.

Along with a chapter on beliefs and conceptions, Grouws' *Handbook* also featured McLeod's chapter on affect and Fennema and Franke's chapter on teacher knowledge. McLeod reviewed the depressingly consistent findings that American students believed that while mathematics was important, it was based mainly on the memorization and execution of rules directed by teachers (e.g. Dossey, Mullis, Lindquist, & Chambers 1988). The negative impact that students' beliefs toward mathematics could have on solving non-routine problems was also highlighted (e.g. Silver, 1985). McLeod also offered his 'reconceptualization' of affect included the progressive, linear view of emotions, attitudes, and beliefs. McLeod offered these constructs as situated along an emotional-cognitive scale with pure emotions at one end of the spectrum and beliefs or knowledge at the other. McLeod argued that raw emotions, through repetition, can lead to attitudes which then ultimately lead to beliefs. McLeod called for more research into teacher affect but that call has remained unanswered (Philipp, 2007). Fennema and Franke began their chapter by acknowledging the important interaction between teacher knowledge and beliefs. They then went on to summarize the major themes regarding teacher knowledge. The authors highlighted theory and research on the different types of teacher knowledge, the ways in which teachers hold knowledge, and the ways in which teacher knowledge impacts instruction. They then extend their review by synthesizing the various models of teacher knowledge. In the 70's and 80's, researchers moved from using number of math courses taken to indicate teacher knowledge to recognizing the importance of pedagogical knowledge, content knowledge, knowledge of learners' cognition, and knowledge situated within instructional contexts. The model proposed by Fennema and Franke indicated an interaction between these four types of knowledge along with an interaction between these various forms of teacher knowledge and beliefs.

A key component of Thompson's synthesis included her argument that beliefs are not static entities to be uncovered as some researchers had suggested. To support this argument, Thompson concluded her synthesis with a discussion of how teachers' conceptions are changed. Thompson highlighted the work of Carpenter, Fennema, Peterson, Chiang, & Loef (1989) who found that teachers' beliefs and practices changed substantially when the teachers learned about student thinking. Thompson called for more in-depth qualitative research to help explain why some teachers' beliefs appeared resistance to change. In line with previous findings on student beliefs (e.g. Posner, Strike, Hewson, & Gertzog, 1982), Thompson noted that some teachers, instead of accommodating their belief system to incorporate a divergent conception, accommodated the conception, based on their belief system, so that it would fit into their existing schema. This tendency to accommodate information to fit an existing belief system has continued to remain a critical barrier to efforts to enact change.

Beliefs Research in the 90's

Beliefs research during the 1990's was still in its early stages. Researchers were attempting to develop instruments for assessing beliefs which were easy to implement and yet reliable. Researchers were concerned with simultaneously revealing the importance of studying beliefs while at the same time demonstrating that the accurate assessment of beliefs was possible. This time period witnessed the inevitable clash of cognitive psychologists' research into student and teacher beliefs with sociocultural research investigating the impact of sociological factors on behaviors. Some researchers justified a focus on only one perspective while others argued for an approach which incorporated both views simultaneously. Due to this prolific and varied interest in beliefs, an educational conference was held specifically aimed at addressing the need to clarify and focus beliefs research in mathematics education.

Beliefs: A Hidden Variable in Mathematics Education?

To date, the most significant review of the literature focused solely on teacher and student beliefs toward mathematics education occurred in the late 90's. Due to increasing and broad international interest in beliefs towards mathematics and the impact which beliefs appeared to have on learning and teaching, an international working conference was held in 1999 at the Mathematics Research Institute of Oberwolfach, Germany in 1999. The conference focused specifically on strengthening the grasp of beliefs and their role in the teaching and learning of mathematics (Mason, 2004). After formalizing the ideas developed during the conference, the book *Beliefs: a Hidden Variable in Mathematics Education?* edited by Leder, Pehkonen, & Torner was published in 2002. The editors utilized contributions from a diversity of international experts to produce a thorough, in-depth synthesis of the research on beliefs at the turn of the century. The volume was divided into three sections: 1) Conceptualization and assessment of beliefs, 2) Studies of teacher beliefs, and 3) Studies of student beliefs.

Conceptualization and assessment of belief. The text began by adding to Thompson's observations concerning the lack of agreement, clarity, and differentiation of the terms beliefs, values, conceptions, belief systems, constructs, attitudes, judgments, opinions, ideologies, perceptions, preconceptions, dispositions, implicit theories, perspectives, etc. McLeod & McLeod (2002) reiterated that there is no single, correct definition of belief, and instead of working to define beliefs, researchers should be guided in their terminology usage by context and audience. The authors indicated that researchers can define beliefs in the following three ways: i) Informally for general audiences, ii) Formally for knowledgeable audiences, and iii) Extended Definitions should be used with technical experts. For example, for general audiences mathematical beliefs could be described as an individual's world view of mathematics (Schoenfeld, 1983). For most researchers, beliefs might be defined as multiply-encoded cognitive/affective configurations to which the individual attributes some "truth value" (Goldin, 2002). And for technical experts, beliefs might be defined in the following way: an individual holds belief $B = (O, C, u, S)$ where O is the object, C is the set of mental associations, u is the model of membership degree functions, and S denotes the evaluation maps (Torner, 2002). However, rather than focusing on developing clear definitions, McLeod & McLeod (2002) stressed the need for researchers to utilize terminology with the appropriate consistency and depth depending on the context and intended audience.

Various views of beliefs dominated the literature in the late 90's and continue to do so. The use of particular views toward beliefs impacted the ways in which researchers attempted to reconcile apparent disparities between beliefs and practices. Wilson & Cooney avoided this disparity entirely by utilizing Scheffler's (1965) definition of beliefs as 'dispositions to act in certain ways'. Other researchers (e.g. Chapman, 2002) defended their methods for assessing ‘espoused’ beliefs measured through interviews and questionnaires and ‘enacted’ beliefs evidenced through practice. The way in which researchers defined beliefs helped identify their theoretical framework. But the dominance of cognitive psychology had been challenged by the emergence of educational research conducted from a sociological perspective.

The first section of this volume also reviewed methods for assessing beliefs. One issue regarding the assessment of beliefs was the role played by the theoretical framework of the researcher. Lerma (2002) indicated that researchers often failed to address the issue of the nature of teacher learning when conducting educational research. Beliefs research underwent a dramatic alteration from cognitive psychology’s focus strictly on the individual. Research in the late 90’s began to include the sociologist’s focus on social context (e.g. Hoyles, 1992; Raymond, 1997). Some researchers went so far as to assert that individual learning never actually occurs (McLeod & McLeod, 2002). One area which was directly affected by the introduction of differing theoretical frameworks was methodology. Several researchers (e.g. Wilson & Cooney, 2002) began to point out the methodological weaknesses of research which attempted to reveal teachers' belief systems through interviews and questionnaires.

Studies of teacher beliefs. Lerman (2002) summarized that reform efforts throughout the 80’s and 90’s asked teachers to change the traditional learning environment. However, classrooms at the turn of the century continued to reflect the traditional performance model. Teachers relied heavily on textbooks and utilized explicit, lecture oriented pedagogy with the teacher “showing” students what to do mathematically. Based on behaviorist psychology, assessments continued to focus on identifying what was missing in students' production. A hierarchical, classification view of mathematics in which students learned mathematics at each level because they would need it for the next level (hierarchical) with mathematics being isolated from other disciplines (classification) continued to dominate the educational environment. Classrooms were still teacher centered with the teacher depicted as the transmitter of knowledge, expected to “know best”, decide what counted as math (strong framing), and to know that their math was the correct math (dualist view). Teachers were being asked to change these views toward teaching. Beliefs took center stage in educational research because of the role they play in encouraging or hindering this change. Reform efforts asked teachers to change from this performance based model to one focused on students demonstrating mathematical competencies. Lerman provided some examples of pedagogy based on the competence model which featured weak framing and invisible pedagogy. The liberal/progressive mode is based on constructivism and views the teacher as facilitator, the populist mode is based on sociology and views the teacher as coordinator, and the emancipatory mode is based on critical theory and also views the teacher as coordinator. However, competence is much harder to assess than performance and requires advanced teacher training which is more expensive.

Lerman (2002) synthesized the six chapters of part II and situated these chapters within the teacher beliefs and change literature. An important generalization made by Lerman was that changing teachers’ practices appeared to hinge on changing teachers’ beliefs. However, some researchers had found that changing what teachers do in the classroom led to changes in beliefs while changes in professed beliefs were not always accompanied by changes in practices. Lerman (2002) noted that every researcher contributing to this volume, whether convinced that changes in beliefs or practices must come first, perceived a cyclical relationship between changes in beliefs and practices. Lerman supported the dialectical relationship proffered by Wilson & Cooney (2002). Their literature review focused on reflection, student understanding, and understanding of content as opposed to pedagogy. Wilson & Conney highlighted findings which revealed the intricate link between reflection and teacher change (e.g. Hart, 2002), the need for teachers to base instructional decision-making on student understanding (e.g. Even, 1999), and the importance of directly addressing teachers' beliefs about content and pedagogy (e.g. Lloyd, 1999).

Researchers had found differing keys to enacting teacher change. The following factors were identified as being important to facilitate change in teachers' beliefs & practices: engagement with colleagues (Hart, 2002; Llinares, 2002), engagement with reform oriented materials (Wilson & Cooney, 2002), conflict between personal goals and the perceived classroom situation (Chapman, 2002; Philippou & Christou, 2002), and reflection (Hart, 2002; Wilson & Cooney, 2002). Llinares (2002) described the learning space for student teachers as the situation in which previous experiences or beliefs were deliberately and directly challenged by conflicting experiences. This work helped explain the barrier to changing beliefs posed by the tendency for beliefs to operate as a perceptive lens. Lerman encouraged researchers to consider emerging research which had revealed contextual factors that could influence teaching and efforts to enact change (e.g. Bernstein, 1999). Overall, Leder, Pehkonen, and Torner (2002) concluded that extensive research into teacher change was conducted between 1980 and 2000 but no consistent pattern had emerged from those efforts.

Studies of student beliefs. Research in the 90's had revealed the need to study students' beliefs towards mathematics due to the impact that beliefs can have on student interest, enjoyment, and motivation in mathematics (e.g. Kloosterman, 2002). Antecedent to the factors which influence teacher beliefs, researchers had found that contextual factors present within the learning environment impacted student beliefs towards mathematics and how it is learned (Lester, 2002). For example, Presmeg (2002) found that students' beliefs about the nature of mathematics constrained their ability to connect mathematics learned at school with home or cultural activities. Yackel & Rasmussen (2002) found support for their contention that beliefs are mostly cognitive in nature but develop within a social framework and that social norming in the classroom can explain changes in student beliefs. Lubienski (2001) found a relationship between ethnicity and social class and disparities in mathematical beliefs and achievement. Work by Tsamir & Tirosh (2002) revealed that students may not believe what teachers think they believe and that some beliefs can be difficult to change.

Lester reiterated the inability to accurately assess beliefs which was highlighted in the teacher beliefs research. While McLeod & McLoed (2002) asserted that the way students are taught to be aware of their beliefs may have more implications for changing those beliefs and improving student learning than anything else teachers might do. They also noted that as of 2002, only one study (Ellerton & Clements, 1994) had been aimed specifically at helping teachers learn how to impact students' beliefs. Lester remarked that much of the beliefs research, unlike so many studies in educational research, has the potential to immediately impact student learning. Improving teachers' understanding of student beliefs can impact students' attitudes, motivation, beliefs, and behavior, and teachers' knowledge, beliefs, and practices.

Other Findings from the 90's

In her observations of teachers attempting to implement technology into their practice, Hoyles (1992) noticed inconsistencies between the teachers' practices and their reported beliefs. At the time, theories to explain how teachers learned reform-based practices had yet to develop (Wilson & Ball, 1996). Hoyles chose to re-examine her linear view of the relationship between beliefs and practice. Instead of concluding that teachers' practices may not align with their beliefs, Hoyles considered Brown, Collins, and Duguid's 1989 situated cognition perspective and concluded that beliefs are constructed within practice and are subsequently contextually situated (Philipp, 2007). By considering the teachers' beliefs as situated within the culture and activity, Hoyles was able to account for the apparent discrepancies between beliefs and practices by considering factors like student level, textbook, and computer use. Later, Raymond (1997) found that contextual factors like the standardized test and maintaining discipline drove teacher practices. The work of Hoyles and Raymond represent early attempts to incorporate sociological views along with psychological views toward teacher beliefs. Richardson conducted several studies which specifically investigated the impact that school culture and teacher beliefs can have on professional development programs. For example, Hamilton and Richardson (1995) concluded that the traditional model of professional development in which experts 'transfer' their knowledge to participants is ineffective in part because that model fails to consider teacher beliefs, the school culture, and the interaction between the two. As will be discussed later, researchers would continue to build on these initial views of beliefs as contextually situated.

In 1993, Altrichter, Posch, & Somekh introduced action research as a method for promoting teacher education. Altrichter, Posch, & Somekh described action research as the systematic reflection of practitioners in action (Llinares & Krainer, 2006). This view toward teaching regards teachers as professionals who systematically investigate their own practice. Action research aligned with the view of teachers as researchers and school-based development (Llinares & Krainer, 2006). Mousely (1992) argued that experience-based research like action research had the power to free teachers from their habitual practices. Krainer (1994) stressed the importance of the relationship between teacher action and reflection. Halai (1999) added that critical reflection and altering the school structure to support collaboration were critical in promoting teachers to learn through action research.

Beliefs Research 2000-Present

There were two significant teacher beliefs literature reviews undertaken in the last decade. Two sections of the *Handbook of Research on the Psychology of Mathematics Education: Past, Present, and Future* edited by Gutierrez & Boero (2006) highlighted significant contributions to the literature on teacher knowledge, beliefs, and practices. Da Ponte & Chapman (2006) focused their review on teacher knowledge and practice while Llinares & Krainer (2006) examined teacher education. Lester's *Second Handbook of Research on Mathematics Teaching and Learning* (2007) built upon the work from the first handbook which included Thompson's 1992 literature review. Philipp (2007) wrote the section of this handbook dealing with beliefs which was entitled *Mathematics*

Teachers' Beliefs and Affect. Philipp included teacher knowledge and practices under the umbrella of beliefs but added the important components of teacher attitude and emotions by including teacher affect. Both of these literature reviews will be discussed at length, but there were also several publications over the last decade which dealt with beliefs but were not included in these literature reviews. Some of these papers were not included based on the criteria used by reviewers while others were published too recently to be considered. Papers which were not included in the major reviews but were particularly relevant to the present study will be discussed following the summaries of the literature reviews.

Literature Review Summaries

Da Ponte and Chapman, 2006. Da Ponte & Chapman considered teacher beliefs a component of teacher knowledge and practice which reflected the ongoing debate regarding terminology. The authors recognized that teacher 'practice' had been used to refer to any professional activity. A professional activity is any setting in which teachers are asked to think, act, or reflect professionally such as the classroom, the school environment, coursework, professional development sessions, and other professional settings. Teacher practice had been conceptualized along a spectrum from action within the classroom to motivations during out of classroom contexts; therefore the authors expressed the need for researchers to make their view of teacher practice explicit.

Da Ponte and Chapman noted the disturbingly consistent finding that teachers continued to lack the deep, broad, and thorough understanding of the mathematics required to meet the NRC's 2001 goal of teaching toward mathematical proficiency. Not unexpectedly, the authors also concluded that most teachers failed to demonstrate practices that aligned with reform efforts and require a deep understanding of mathematics. These same studies had yet to identify which variables (knowledge, pedagogical content knowledge, or cognitive level) were the key to understanding teacher practices. Multiple informative and theoretical models had been used in the study of teacher beliefs, conceptions, and practice, but alternative views had developed which suggested that knowledge of mathematics teaching was an issue of professional activity within educational, cultural, societal, and other contextual factors. The authors highlighted a continued emphasis on the importance of locating teacher beliefs as an individual conception formed within the societal context. Gates (2001) indicated that teachers' beliefs are significantly impacted by society's views toward learning, the role of education, the role of teachers, and ideas about priorities for teacher development. Da Ponte and Chapman noted the lack of papers which had combined social and individual levels of analysis. They expressed the need for "a better grasp regarding how educational, professional and institutional factors influence teachers' practices." (p. 488)

Llinares and Krainer, 2006. Llinares and Krainer focused their literature review on teacher education. Researchers' conception of the knowledge required for teaching mathematics had altered to incorporate a teachers' ability to understand student thinking. Researchers had recognized that content knowledge needed to be situated within the context of teaching. In addition to reiterating the need for teachers to reflect on their practice, Llinares and Krainer indicated that critical reflection was a key to professional growth, and the professional development tasks in which teachers engaged made a significant difference. Professional development programs which provided teachers with the opportunity to reflect on their direct experience with reform-based practices were found to be particularly effective. Llinares and Krainer highlighted the findings from CGI studies that active reflection on student learning and sharing with colleagues had a positive impact of teacher beliefs and knowledge. Teachers participating in CGI also appeared to have continued to develop professionally years later (Franke, Carpenter, Levi, & Fennema, 2001).

The authors went on to provide a historical account of research in another promising arena: action research. The authors referred to Altrichter, Posch, & Somekh 1993's definition of action research as the improvement of teaching through the systematic reflection of practitioners in action. In action research, teachers are viewed as researchers. Several researchers argued that experience-based research, like action research, cognitively guided instruction, and Hiebert, Morris, and Glass's experimental model of teaching, appeared to improve professional development effectiveness by helping teachers reconsider traditional practices (Mousely, 1992), causing more dramatic changes in beliefs and practices (Ellerton, 1996), and promoting generative growth (Franke, Carpenter, Levi, & Fennema, 2001). But critical reflection and within school structural changes are needed to promote experienced-based teacher learning (Halai, 1999). To optimize effectiveness, professional development programs should include the development of a community of practice to insure social support and productive collaboration. Llinares and Krainer also indicated the need to create a model to help understand teacher education: “If we regard a teachers' professional development as a learning process, we must create a model of how we understand this learning process and the factors that influence it" (p. 445).

Philipp, 2007. Philipp's review focused on what researchers had to say about teacher beliefs and affect. Philipp summarized Thompson's review of beliefs and McLeod's review of affect from the 1992 *Handbook* before reviewing the literature since the first *Handbook*. The review began with the typical discussion of beliefs terminology with Philipp reiterating the lack of terminology agreement and the need for researchers to properly use and specify terminology. Philipp provided an important difference between beliefs and knowledge. For Philipp, a conception is a belief for an individual if he or she can respect a contrasting conception as reasonable and intelligent while the conception is knowledge if contrasting conceptions are not respected.

Philipp also noted five big occurrences which have affected educational research in mathematics: 1) Acceptance of NCTM's Standards, 2) Increased number of publishing outlets, 3) Increased politicization in education, 4) Technological advancements, and 5) Emergence of sociocultural views of learning. Much of the impact on educational research has been a result of reform efforts. However, these reform efforts have failed to impact classroom instruction due to teachers' beliefs about teaching mathematics (Ross, McDougall, Hogaboam-Gray, 2002) and because teaching is cultural (Stevenson & Stigler, 1992). Other findings furthered the importance of studying teacher beliefs. Contributing to the consistent finding that beliefs impact instruction, use of curricular resources, and technology implementation, Philipp added that the beliefs of curriculum designers and teachers must align for curricula to be implemented as intended (Collopy, 2003; Remillard & Bryans, 2004). Philipp also argued for the importance of studying teacher affect. The inclusion of a positive disposition toward mathematics in the NRC's 5 stranded definition of mathematical proficiency revealed the importance of teacher affect.

Teacher affect provides the motivation for many teacher decisions, but it has received much less attention than teacher beliefs. Simon & Tzur (1999) argued for studying teacher perspectives in general. To take this broader view, Simon & Tzur used of a *set* of collected data and in-depth qualitative methods to examine knowledge, beliefs, values, attitudes, intuitions, feelings, and practices.

Context has played an important role in researchers' efforts to understand inconsistencies between teachers' beliefs and practices. In general, researchers have found that teachers' practices tend to align with beliefs toward mathematics more so than beliefs toward teaching or learning. However, Philipp made specific mention of research conducted by Sztajn (2003). Sztajn investigated two teachers with similar beliefs toward mathematics, teaching, and learning who were situated in different contexts. Sztajn found that the teachers exhibited significantly different practices due to contextual factors and differing beliefs toward society and education. Sztajn's work supported Skott (2001) and Hoyle's (1992) assertion that contextual factors impact behaviors. Skott argued that beliefs do not depend on contextual factors, but rather, behaviors reflect motivations which are contextually dependent. Philipp asserted that researchers should assume that inconsistencies do not exist because attempts to explain why beliefs and practices appear inconsistent will yield improved models. Many mathematics education researchers have adopted Cobb's (1995) sociocultural and Wenger's (1998) participatory learning theory frameworks. Philipp supported the arguments of Lerman (1998), Van Zoest & Bohl (2005), and Thompson & Cobb (1998) that researchers must be able to analyze teachers as individuals through a psychological lens while also examining the teacher as a member of a group through a sociocultural lens. Philipp went on to declare that how researchers negotiate between constructivist and sociocultural perspectives is an important issue for the future of research on teachers' beliefs.

Philipp provided a brief review of models of teacher change which will be discussed in detail in the next section. Philipp offered that determining whether change in practice precedes beliefs or not is less important than providing appropriate support to allow teachers to change both beliefs and practices. In fact, he suspected that future research would show that the most meaningful changes occur when beliefs and practices change together. He reiterated the important role which reflection plays in changing teachers’ beliefs and practices. Philipp highlighted the need for teachers to have the opportunity to learn about student thinking. Teachers' beliefs tend to change as a result of observing student thinking (D'Ambrosio & Campos, 1992; Knapp & Peterson, 1995; Vacc & Bright, 1999) due in part to the intensity of the experience (Ambrose, 2004). A significant challenge facing researchers is determining how to change teacher beliefs because beliefs inherently impact perception. The greatest barrier to achieving change is that researchers must find a way to provide evidence which forces teachers to question their beliefs when teachers struggle to see what they do not already believe. Philipp asserted that reflection was the key to solving this quandary: "When practicing teachers have the opportunity to reflect upon innovative reform-oriented curricula they are using, upon their own students' mathematical thinking, or upon other aspects of their practice, their beliefs and practices change" (p. 309). With this single statement, Philipp indicated that teachers must be able to properly implement reform-oriented curricula, examine student thinking, and reflect on their practice.

Other Contributions

Muis. In an effort to help build a cohesive theoretical framework for the study of learner's epistemological beliefs in mathematics education, Muis (2004) conducted a critical review of the 33 empirical studies which met predetermined criteria and focused on students' mathematical beliefs from a psychological perspective or within mathematics education. Based on the findings of these studies, Muis distinguished between 'availing' beliefs, those positively related to quality learning and achievement, and 'nonavailing' beliefs, those that do not affect learning or achievement in a positive way. The following beliefs were identified as non-availing: math is about memorizing procedures, not understanding and connecting concepts; mathematics consists of unrelated, disconnected bits of information; mathematical knowledge is static; math must be passively received from teachers or textbooks; students cannot construct their own understanding of mathematics or learn math through logic and reasoning; only those born with the 'math gene' can really do mathematics; learning math should occur quickly. Students' beliefs have tended to become more availing over time. However, students from elementary to college level tended to have unavailing beliefs toward mathematics. Muis also described research indicating that classroom context impacts students' beliefs.

Students tended to have less availing beliefs toward mathematics than other disciplines. In most mathematics classrooms, students tend to be immersed in learning environments which focus on speed, accuracy, and memorization of rules and procedures. The prevalent teacher directed environment has typically isolated these practiced routines from other concepts. This traditional instruction has been associated with the belief that learning should occur quickly; there is only one right answer; success requires innate ability; mathematical knowledge is unchanging and consists of isolated pieces of information; and the teacher is the mathematical authority. Researchers have yet to demonstrate a causal relationship between the traditional learning environment and students' unavailing beliefs, but the relevant data support such a claim. Students' beliefs tend to reflect their learning environment. Most studies focused on improving students' beliefs through instructional changes found positive results within a relatively short period of time. The NCTM (1980, 1989, 1993) and the National Research Council (1989) called for reform based on the widely held perception that these prevalent and unavailing beliefs have been detrimental to student achievement. Reform-based teaching practices have subsequently focused on individual student construction of mathematics within meaningful contexts. Students should be given appropriate time to learn from engagement in collaborative discourse and problem solving. This type of instruction encourages students to learn mathematics through effort over time and to view mathematics concepts as inter-related and inter-disciplinary.

Hiebert, Morris, and Glass. In 2003, Hiebert, Morris and Glass proposed their "Experimental Model of Teaching" for pre-service teacher training to address the enduring problem of how to design preparation programs that improve teacher practice (Borko et al., 1992; Cooney, 1985, 1994; Ebby, 2000; Lortie, 1975). This model for teacher education built on the Fennema and Carpenter's work with CGI. In addition to helping pre-service teachers obtain mathematical proficiency themselves as recommend by the National Research Council (2001), Hiebert, Morris, and Glass created this model to help train teachers to learn from classroom experiences. They argued that since teaching is such a complex profession, it is simply unreasonable to expect prospective teachers to enter the field as experts. Moreover, in-service classrooms offer the best environment for teachers to learn how to teach (Ball & Cohen, 1999; Clark, 2001; Jaworski, 1998; Schön, 1991), while teacher preparation programs are better suited for preparing prospective teachers to learn from their experiences when they become teachers (Masingila & Doerr, 2002; Moyer & Milewicz, 2002). And novice teachers need to know how to create a community of practice within their schools as many U. S. schools lack the organizational structure to provide teachers with the support required to utilize classrooms as learning sites (Darling-Hammond, 1997).

Based on this model, teachers must know how to treat lessons as experiments in order to learn from their classroom experiences, since experience alone does not ensure improved performance (Sullivan, 2002). This model shared many characteristics with design-based research, design research, and action research, but this experimental model of teaching is not a research method to be applied with the expertise of a researcher with formal data collection and a specified product. Rather, Hiebert, Morris, and Glass were attempting to train prospective teachers to use the classroom as a learning tool. By focusing on intensive and systematic lesson planning combined with critical reflection and examination of lesson effectiveness, the authors hoped to train pre-service teachers to become generative professionals who continue to develop professionally as a result of learning from lesson planning and reflection on lesson effectiveness.

For teachers to treat lessons as experiments, they must design lessons with clear goals in mind, monitor their implementation, collect feedback, and interpret the feedback in order to revise and improve future practice. To do so, teachers must have a clear goal for each lesson and hypotheses which link instructional practices to learning outcomes. In this way, teachers can ‘test’ their instructional practices by examining the impact on learning outcomes. Hiebert, Morris, and Glass were adamant that learning goals needed to be defined in terms of student thinking as recommended by Wittrock (1986) and Simon, Tzur, Heinz, Smith, & Kinzel (1999). They also indicated that focusing on student thinking also provides rich data to help inform teaching. These authors felt that the use of student thinking as the measure of instructional effectiveness was the key to this model of professional growth.

Rowan, Hill, & Ball. Though logic dictates that teachers' knowledge should impact student learning, there has been a lack of empirical evidence confirming this assumption (Wayne & Youngs, 2003). For decades, researchers observed an inconsistent relationship between teacher knowledge and gains in student achievement. However, researchers recognized two key problems with measures of teacher knowledge. Firstly, measures like courses taken, degrees attained, and basic skills tests were not good indicators of teacher knowledge. Secondly, teaching mathematics well requires more than simply knowing mathematics. Since Shulman's 1986 introduction of pedagogical content knowledge, researchers have come to recognize that, in addition to knowing mathematics, teachers must be able to represent mathematical concepts, explain basic rules and procedures, and analyze students' solutions and explanations. In addition to a lack of good teacher knowledge indicators, only a few studies have attempted to directly measure teachers' knowledge of teaching mathematics and correlate it with achievement gains. To address this issue, Hill, Schilling, and Ball (2004) created a 30 item, multiple choice instrument designed to measure teachers' *mathematical knowledge for teaching* which they termed Content Knowledge for Teaching (CKT). The instrument was designed to measure teachers' ability to explain terms and concepts, interpret students' response, judge and correct textbook treatments of topics, use representations, and provide appropriate examples. This instrument had already met validity requirements, and Hill, Rowan, and Ball intended to use it to show a strong relationship between teacher knowledge and gains in student achievement after accounting for other factors.

Hill, Rowan, and Ball collected data from 1,190 first grade students, 1,773 third grade students, 334 first grade teachers, and 365 third grade teachers from 115 elementary schools. Data were collected from the 2000-2001 school year until the 2003-2004 school year. The authors went to extensive efforts to insure a nationally representative sample, instrument validity, and to compensate for data issues. The authors also controlled for key student-level and teacher-level covariates. Using the CKT instrument, Hill, Rowan, and Ball found a strong, reliable, positive correlation between the mathematics achievement gains of both first and third graders and teacher knowledge. The authors also found a strong, positive relationship between achievement gains and class time. These findings point to the need for researchers to further clarify the knowledge required for teaching while also using high-quality instruments like the CKT to insure proper measurement of teacher knowledge.

Polly. Research on reform effectiveness has found support for learner-centered instruction. Components of learner-centered instruction have been related to gains in achievement such as creating authentic learning tasks, focusing on evidence of learning, and asking students to pose questions and analyze problem solving strategies. A set of principles for learner-centered instruction were first created by the American Psychological Association in 1997 (APA Work Group, 1997) and then later extended for K-12 learners (McCombs & Whisler, 1997; McCombs, 2003). Cornelius-White (2007) found that learner-centered instruction may have improved student learning in historically challenging areas. Unfortunately, several studies have confirmed that teachers tend to profess a strong belief in learner-centered instruction while demonstrating practices which are inconsistent with those beliefs (e.g. Cognitive and Technology Group at Vanderbilt [CTGV], 1997; Cohen, 2005; Peterson, 1990; Stein & Kim, 2009).

Polly (2009) utilized triangulated data sources to document the change process of two elementary teachers engaged in a professional development program. The program was designed using a set of research-based *Principles* which indicated that learner-centered professional development should focus on six areas: student learning issues, teacher ownership, professional collaboration, comprehensive change processes, teacher knowledge, and reflection driven by student work. Most professional development sessions featured designers providing examples of how participants should implement instructional tasks. As had been observed in previous studies, teachers' beliefs and practices were inconsistent. Despite feeling as if they were implementing the professional development tasks as intended, teachers tended to focus on showing students algorithms for completing tasks. Teachers showed an improved ability to pose questions to students but tended to pose mostly cognitively low-level questions. However, when designers co-planned lessons with participants, instead of the more traditional sessions, implementation was aligned more strongly with the learner-centered design. Also, teachers tended to ask more high-level questions when implementing lessons that were co-planned with developers.

Researchers (e.g. Orrill et al., 2006; Peterson, Putnam, Vredevoogd, & Reineke, 1992; Stein, Remillard, & Smith, 2007) have noted that professional development participants often implement instructional tasks in ways that are inconsistent with their design despite espousing beliefs consistent with the professional development. These researchers have argued that differing beliefs toward effective teaching can explain these discrepancies. Polly, however, offered a different perspective. As noted by Heck, Banilower, Weiss, & Rosenberg (2008), Hoetker & Ahlbrand (1969), and Tarr et al. (2008), the classroom setting itself can pose barriers to teacher change. Polly concluded that classroom-based support and strong scaffolding of professional development tasks can help overcome contextual barriers and help insure implementation of instructional tasks as intended by professional development designers.

Wilkins. Since most research investigating teacher beliefs has been qualitative in nature and conducted with small samples, quantitative studies with large samples are needed (Adler, Ball, Krainer, Lin, & Novatna, 2005; Mewborn, 2001; Philipp, 2007). Large scale quantitative studies are required in order to generate and test models (Adler et al, 2005; Philipp, 2007). Wilkins (2008) conducted a study with 481 elementary and secondary teachers from different school districts. The study was designed to test Ernest's 1989 model of the variables related to teacher instruction. Ernest posited that teachers' instructional practices were a function of mathematical content knowledge, attitudes toward mathematics, and beliefs about effective instruction. Data on teacher background characteristics (teaching experience, math courses taken, and level of educational attainment) were also included in the model. Wilkins utilized pathway analysis to test Ernest's theorized model of the relationships and inter-relationships between content knowledge, attitudes, beliefs, and practices.

Statistical analysis revealed a viable fit between the data and the hypothesized model that teacher knowledge, attitudes, and beliefs influence instructional practices. Wilkins found that teacher background characteristics had only indirect effects on instructional practice. Content knowledge, attitudes, and beliefs all influenced instructional practice with attitude and beliefs having positive relationships to the use of inquiry-based instructional practices while content knowledge had a negative relationship. Beliefs had the strongest direct effect on instructional practice as well as mediating the effects of teachers' knowledge and attitudes. In addition to supporting previous findings regarding the relationship between teacher beliefs and practice, this study revealed that teacher beliefs, as hypothesized by some researchers, could be the key factor in changing teachers' practices. However, this study also questioned previous findings that teacher knowledge and practices were related positively. Wilkins provided a potential explanation which also relied on existing but untested theory.

The negative relationship between knowledge and practice found by Wilkins contrasted strikingly with previous findings (e.g. Fennema & Franke, 1992). Wilkins theorized that perhaps, some teachers, with higher content knowledge, might believe they were successful as a result of the traditional instruction to which they were exposed and subsequently follow that seemingly successful model. However teachers who had negative experiences with traditional instructional methods and now hope to provide better learning environments for their students might be more likely to favor non-traditional approaches (Anderson, White, & Sullivan, 2005). Also, teachers who were less successful mathematically might tend to empathize with students experiencing reform-based pedagogy (Brand and Wilkins, 2007). Overall, Wilkins recommended that professional development programs should focus on improving teacher attitudes and beliefs which ultimately drive instructional practices that are, at best, enhanced by strong content knowledge. Teachers' beliefs about the effectiveness of particular instructional methods largely determine how teachers will teach. To change teachers' beliefs about instructional effectiveness, professional development programs must insure that teachers experience, first-hand, the positive value of instructional practices that promote student understanding (Szydlik, Szydlik, & Benson, 2003; Lloyd, 1999, 2002, 1999; Borasi, Fonzi, Smith, & Rose, 1999).

Swan. In 2004, Swan developed an instrument to measure teachers' beliefs and practices. The instrument was based on Ernest's 1989 model of teachers' belief systems and Askew's 1997 characterization of teachers' orientations. Ernest (1991b) divided a teacher's belief system into the following three conceptions: the nature of mathematics as a subject, the nature of mathematics teaching, and the nature of the process of students learning mathematics. Askew (1997) characterized teachers' orientation toward these three components as transmission, discovery, or connectionist. The instrument was also designed to determine the extent to which teachers' were teacher-centered versus student-centered in their practices. Swan also utilized this instrument to spur professional discourse. Only three of the 43 participants claimed to teach in ways that aligned with their beliefs. Teachers blamed several contextual factors for these discrepancies such as lack of resources, school culture pressures, and low expectations, but the perceived need to cover the expected content was the most salient factor. Swan also used this instrument in his 2008 (in press) study.

The findings from Swan (in press) provided evidence which supported a dialectical relationship between beliefs and practices. Swan found, as expected, that teachers' use of reform-based, collaborative instructional tasks was mediated by their beliefs. However, he also found that teachers' beliefs changed based on the ways in which they implemented the reform-oriented tasks. Transmission oriented teachers who implemented the tasks in a teacher-centered fashion tended to show little change in teacher beliefs. Students in these classrooms showed no improvement in achievement over the control group. However, transmission oriented teachers who implemented the tasks as intended showed distinct changes in beliefs and their students showed achievement gains. Overall, the more teachers implemented the instructional tasks as intended, the more their beliefs aligned with a reform-based orientation and the greater the gains in student achievement. Of interest, only three of the thirty-six participants in Swan's study claimed that their practices were consistent with their beliefs. The other participants felt that they compromised their beliefs and focused on teacher-centered, procedural instruction due to contextual pressures such as time restrictions, lack of resources, lack of knowledge, and student behavior, motivation and expectations. Research has consistently shown that teacher beliefs impact implementation of reform-oriented practices, but in Swan's study, teacher implementation of reform-oriented tasks also appeared to impact teachers' beliefs.

Key Findings from Beliefs Research

There are several areas from the wealth of research on beliefs that could be highlighted, but this summary will focus on those areas which are of greatest relevance to the current study. In the 90's, there were arguments between teacher change theorists regarding the relationship between beliefs and practices. Pajares argued that beliefs have to change before practices can change. Guskey argued that teachers first try new practices and then only after experiencing repeated success with those new practices do beliefs actually change. However, most researchers currently investigate beliefs and practices as a dialectical relationship.

Researchers have also started to view teacher practices in various ways. A term that was once restricted to classroom instruction can now apply to almost any professional activity in which a teacher engages as a professional educator. Since beliefs are not only dispositions toward action but also filters through which an individual perceives the world, the significance of teachers' ability to experiment with new practices and objectively measure the effectiveness of those practices becomes all too clear. Of equal importance is the type of data teachers choose as indicators of lesson effectiveness. These issues also highlight the importance of reflection. There is no question that critical reflection plays a key role in teacher change. In concert with reflection, researchers have found that teachers who focus on student thinking appear to grow professionally to a greater extent and for an extended period of time. Researchers have also thoroughly investigated the impact of teacher knowledge. The mediating effect of teacher knowledge on the interaction between beliefs and practices has been clearly demonstrated.

The interaction between beliefs and practices has rarely been discussed without recognition of apparent inconsistencies between the two. As instruments to measure beliefs and practices have improved, these inconsistencies have become more salient. While some researchers have explained inconsistencies by focusing on competing beliefs, other researchers have argued that beliefs cannot be accurately measured and instead teacher actions should be the focus. However, the most compelling research has focused on understanding the interaction between beliefs and practices in light of context factors. Alexander (2001) argued that researchers should not and cannot separate educational practices from culture while Hiebert & Stigler (2000) claimed that teaching is culturally embedded. However, since this view of the interaction represents a blending of psychological and sociological perspectives, researchers have not had a complete model from which to engage in these investigations. The following theoretical framework was designed to achieve that goal.

CHAPTER 3: THEORETICAL FRAMEWORK

This theoretical framework will begin with an account of the development of sociocultural constructivism which provided the underpinnings for the model for teacher change created for this study. A discussion of the definitions of key terms used in this paper will also be included. Following the review of sociocultural constructivism and definitions of key terms, a historical account of efforts to model teacher change will be provided. The final section of the theoretical framework will include a thorough description of the proposed model of teacher change: *The Contextualized Interaction Model of Teacher Change*. This proposed model merges components of previous teacher change models while accounting for, and remaining consistent with, existing data and research findings. The *Contextualized Interaction Model* (*CI Model*) will then be used to examine the research questions.

Sociocultural Constructivism

The Emergence of the Sociocultural Perspective

In 1995, Rogoff and Chavajay summarized the transition from cognitive psychology's focus on individual cognitive development to a focus on cognitive development contextualized within cultural factors. In the 1960s and 70s, cross-cultural psychologists began to investigate variations on cognitive tasks in diverse cultures. Prior to these cross-cultural studies, cognitive psychologists had assumed, in accordance with Piaget's theories on cognitive development, that cognitive task performance was generalizable and that cognitive development was independent of culture. However, researchers (e.g. Ashton, 1975) found strong relationships between localized school practices and cognitive tasks. Children of similar ages with significantly different educational backgrounds performed in strikingly different ways on certain types of cognitive tasks. For example, several researchers found that only children with extensive schooling reached Piaget's formal operational stage of development (Ashton, 1975; Goodnow, 1962; Laurendeau-Bendavid, 1977; Super, 1979). These findings so directly contradicted Piaget's claim that his developmental stages were context free that Piaget (1972) acknowledged the culturally dependency of the formal operational stage of development. For some cognitive tasks, like conservation, some researchers (e. g. Laurendeau-Bendavid, 1977) found no differences in the performance of schooled and non-schooled students. For other cognitive tasks, researchers (e. g. Goodnow, 1962) found extensive schooling limited the daily experiences that provide the foundation for good judgment. By the 1980's, the findings from the cross-cultural studies had pushed researchers to conclude that schooling and literacy could strongly impact performance. This research also led to advent of sociohistorical and sociocultural research.

Just as research findings raised questions about the generality of Piaget's developmental stages, the translation of Vygotsky's work into English provided a theoretical perspective which helped account for these findings. Vygotsky's theories drove researchers to understand the social and cultural-historical factors which impact the development and use of individual cognition. The underlying assumption of the sociocultural perspective is that individual, social, and cultural levels are inseparable. Individuals and society develop through shared involvement. Cultural-historical tools, practices, and institutions influence the cognitive development of the individual just as the individual impacts these tools, practices, and institutions. Competing with this sociocultural perspective is the constructivist perspective toward learning. Ultimately these two competing views would lead to one, merged perspective on education.

Cobb's Sociocultural Constructivism

In the same year that Rogoff and Chavajay reviewed the transition toward Vygosky's sociocultural perspective initiated by the cross-cultural studies of the 1970's, Cobb (1995) introduced sociocultural constructivism. Cobb's goal was to reveal the ways in which these two apparently dichotomous perspectives could, and should, be utilized in a complementary fashion by researchers. Cobb summarized that sociocultural theorists, in the Vygotskian tradition, view cognitive development as the social enculturation of intellectual inheritance. Sociocultural theory emphasizes the roles played by social interaction and culturally developed tools. Children learn only through interaction with classmates, teachers, and parents and through the use of sociohistorically developed mathematical symbols and conventions. The development of each individual child only occurs within the culture in which they develop. However, constructivists, in the Piagetian tradition, view the cognitive development of children as the individual, active construction of conceptual reorganization. Constructivism focuses on the individual students' cognitive growth which is influenced by social context and the use of socially developed tools. A child's cognitive development is constructed within those contextual factors. The influence of social factors is different for each individual learner because learners' construct their own understanding of cultural factors and sociohistorically developed mathematical tools. To summarize, socioculturalists tend to account for concept development socially while constructivists account for concept development cognitively.

Cobb introduced the sociocultural constructivist perspective to help explain findings from a 1995 study of the role played by hundreds boards in the development of the concepts of counting by tens and ones for four second graders. Cobb found that use of the hundreds boards did not support the children's construction of increasingly sophisticated conceptions of tens. Rather, the children's construction of place-value led to their improved use of the hundreds board. Of far greater significance however, Cobb provided a seminal example of the use of the sociocultural and constructivist perspectives to analyze the data. For example, Cobb noted that the analysis from the constructivist perspective would have focused on each child's individual construction of the hundreds board as a mathematical tool. Each child's use of the hundreds board contributed to local mathematical practices in ways which both enabled and constrained individual development. From the sociocultural perspective, the conclusions might have focused on the hundreds board as a sociohistorically developed mathematical tool advocated by the teacher. Once students began utilizing this tool, the students would have internalized the use of the tool which would then regulate their concept development. At this point, Cobb argued that a constructivist perspective was required to describe the interaction which occurs when students use a sociohistorical mathematical tool.

Cobb cited Rogoff's (1990) reconciliation of the problem posed by 'internalization'. Rogoff noted that internalization assumes that the lesson to be learned is brought across a barrier into the child's mind. But these barriers could not exist within the socially interactive use of a sociohistorical tool; therefore there was no separate process of internalization. Rather, Rogoff proposed that researchers should instead focus on what the meaning of the tool was for the child. Cobb then extended Rogoff's ideas by explaining that the issue no longer focused on explaining how students' use of sociohistorically developed mathematical tools lead to children's internalization of culturally organized ways of thinking. Instead, the central issue became explaining how collective meaning evolves from the interaction between individual students' symbolic meanings and the culturally established, consensual meaning. Cobb's analysis exemplified this approach as he observed one student, John, who lacked an understanding of counting by tens but had acquired the notation regularities that were consensual with the teacher's use of the hundreds board. Another student, Janet, appeared to have acquired these same notation regularities. But Cobb's sociocultural constructivist investigation revealed that in fact Janet's individual development of an understanding of place-value had allowed her to convey numerical meaning through her use of the socially consensual notation regularities which she had been shown by the teacher. Just as the cognitive development of the individual must be influenced by the sociocultural factors in which that individual develops, so must the evolution of sociohistorical mathematical concepts and tools be influenced by each individual's social interaction with that concept or tool.

Cobb found that the apparently dichotomous perspectives of sociocultural and constructivist theory in fact complemented each other. Cobb argued that the two perspectives were developed to address different issues. Vygotsky's sociocultural perspective evolved to help investigate the ways in which social factors influence cognitive development. While Piaget's constructivist perspective evolved to help explain the ways in which children developed and contributed to social factors. With the sociocultural constructivist perspective, Cobb argued that the two perspectives should be used to complement each other and subsequently create a more accurate investigation into the interaction between sociocultural factors and individual development. This hybrid theory introduced by Cobb in 1995 has been increasingly adopted by mathematics education researchers (Philipp, 2007).

Definitions & Key Terms

As has been discussed at length, researchers have yet to develop common definitions for beliefs, knowledge, attitudes, etc. However, researchers need to insure that they indicate which definitions they are using while also utilizing terminology which is appropriate for the intended audience. For the purposes of this paper, definitions will be provided assuming an informed audience that is familiar with educational research. However, terms will be clarified in very formal and informal ways to address a variety of readers. The definitions provided below rely heavily on the definitions used by Philipp in 2007 and follow McLeod's (1992) linear model of affect.

Practice. Teacher practice has been used with varying degrees of specificity. Practice can refer strictly to classroom-based teacher behaviors and as broadly as referring to any professional activity in which teachers are asked to think, act, or reflect in any professional fashion. Since the focus on this study was classroom-based teacher behaviors, practice and instructional practice will be used to refer to teachers' actions and behaviors within the classroom environment. The term professional activity will be used to refer to teacher actions or behaviors outside the classroom environment.

Conceptions. A conception is a cognitive construct, mental structure, or general notion. Beliefs, knowledge, values, meanings, concepts, rules, propositions, images, and preferences are all types of conceptions.

Emotions. An emotion is a state of consciousness or feeling rather than a cognitive process or construct. Emotions are less cognitive and change more rapidly than attitudes and beliefs. Emotions can have a positive or negative affect attached to them.

Attitudes. Attitudes are manners of acting, feeling, or thinking that indicate one's disposition. They are more cognitive and less subject to change than emotions but less cognitive and change more rapidly than beliefs. Like emotions, attitudes can impact consciousness positively or negatively but attitudes are felt with less intensity than emotions.

Beliefs. Beliefs are a psychological conception that a premise or understanding is thought to be true. Beliefs are the most cognitive component of affect but are harder to change and felt with less intensity than attitudes and emotions. Beliefs are dispositions toward both action and perception. Beliefs regarding a particular construct guide an individual's behaviors while also acting as the lens through which the individual perceives that construct. Beliefs can be held with varying degrees of conviction; an individual can respect contradictory beliefs held by others. If individual A holds conception X as a belief, then individual A can respect conception Y of individual B even if conception Y directly conflicts with conception X. Individual B will be considered as having differing beliefs. However, these differing beliefs may illicit an emotional reaction if either individual feels as if their beliefs are being challenged.

Example of emotions, attitudes, and beliefs. With repetition over time an individual's emotional reaction to some stimulus can lead to the development of an attitude toward that construct which can then develop into a belief. For example, a student might become very stressed or anxious while taking his first timed test of math facts. Since these five minute quizzes occur each week, he might come to dread these quizzes and develop a negative attitude. After struggling all year with these math fact quizzes, his initial emotional reaction to these quizzes could have developed into a negative attitude toward math class in general. One year later, the student might have come to believe that mathematics is all about doing what the teacher has shown you to do quickly. And since he can't recall his math facts quickly, he might even believe that he is bad at math or that math isn't very important since it's just memorization.

Knowledge. Knowledge is a conception which an individual believes has been established as true. Since proven true, these conceptions are not held with the emotion of beliefs, but these conceptions can only be changed if the individual holding the conception as knowledge is receptive to evidence which could prove them false. If individual A holds conception X as knowledge, then individual A will not respect conception Y of individual B if conception Y conflicts with conception X. Individual B will simply be considered wrong for holding conception Y. Individual A will not feel challenged since individual B is simply wrong and will therefore have no emotional reaction.

Values. A value is a conception held with great conviction in which an individual believes. Values are not proven true or false; rather the conception is viewed as desirable or undesirable. Values so greatly impact perception that they are usually impervious to change and instead act as the foundation upon which an individual builds other conceptions. Like knowledge, if individual A holds conception X as a value, then individual A will not respect conception Y of individual B if conception Y conflicts with conception X. And like beliefs, individual A may have an emotional reaction if he feels challenged by individual B which is likely since values are held with such conviction.

Example of beliefs, knowledge, and values. Knowledge is a conception which an individual believes he or she knows to be true, while beliefs are conceptions that are thought or felt by the individual to be true. Individuals believe *in* values as opposed to believing a value to be *true*. An important component of values is that the individual who holds a conception as a value believes that it is not possible for the value to be proven false. An example should help distinguish between ways in which the terms knowledge, beliefs, and values will be used in this paper. Let us consider the conception that it's important for students to learn mathematics. Suppose that a teacher, Anne, holds this conception as a belief. Then if another individual, Bob, claims that it is not important for students to learn math, then Anne might be interested in hearing why Bob feels that way. Perhaps Bob doesn't think that math is very important because he's very successful despite doing so poorly in math in school. Because Anne holds this conception as a belief, she might try to help Bob understand that he does use math a lot but simply doesn't recognize the relationship between the mathematics he studied in school and the math he uses routinely in the real world. It might be that this difference in beliefs is really due to differing views toward mathematics. But this scenario is different if Anne holds this conception as a value. If Anne values the importance of students learning mathematics, then she is likely to have an emotional reaction to Bob's claim that learning math is not important. Anne might try to change Bob's mind due to her conviction of the value of students learning mathematics. And if Anne holds this construct as knowledge, then she might dispassionately dismiss Bob's contention, and explain all the reasons that prove that students need to learn mathematics.

Modeling Teacher Change

The drive to create a model to help explain how teachers' beliefs, practices, and knowledge change began in the 1980's. The deficits in the United States mathematics program had become apparent in the 1960's when Russia won the race into space. However, reform efforts initiated in response to Sputnik had been proven unsuccessful through reports like *A Nation at Risk* in 1983. Researchers and educators had searched for methods to improve student achievement, but poor research methods and weak indicators had resulted in continued failures to identify any teacher or school characteristics that correlated with increase student achievement (e.g. Begle, 1979). Researchers strove to utilize better methods and acquire stronger indicators. In depth qualitative research revealed the impact which student beliefs appeared to have on student achievement and teacher practices (e.g. Schoenfeld, 1985; Thompson, 1984). Researchers had noted the inability of most professional development programs impact student achievement, teacher practices, or teacher beliefs (e.g. Cuban, 1990). Since professional development programs appeared unsuccessful, researchers questioned the model of teacher change upon which professional development programs were designed.

Starting in the 80's, researchers have proposed models of teacher change which have become progressively more consistent with the existing data. These models have grown from overly simplistic to overly complicated, from reflecting no educational perspectives to incorporating arguably exclusionary perspectives. The review which follows will provide a historical account of models of teacher change while also reviewing the change factors which have not been reflected by these models.

Guskey's Linear Model of Teacher Change

For decades, professional development in the United States has assumed the form of short meetings, one to three day-long workshops, and one to two week-long summer workshops (National Research Council, 2002a; Smith, 2001; Guskey, 2000). This design has been based on the goal of changing teachers' practices by changing their beliefs during professional development workshops (Guskey, 1985). It was assumed that teacher practices would change as a result of changing teacher beliefs and that these changes in practices would ultimately result in improved student achievement (Guskey, 2002). See Figure 1 below for a representation of this model of teacher change.

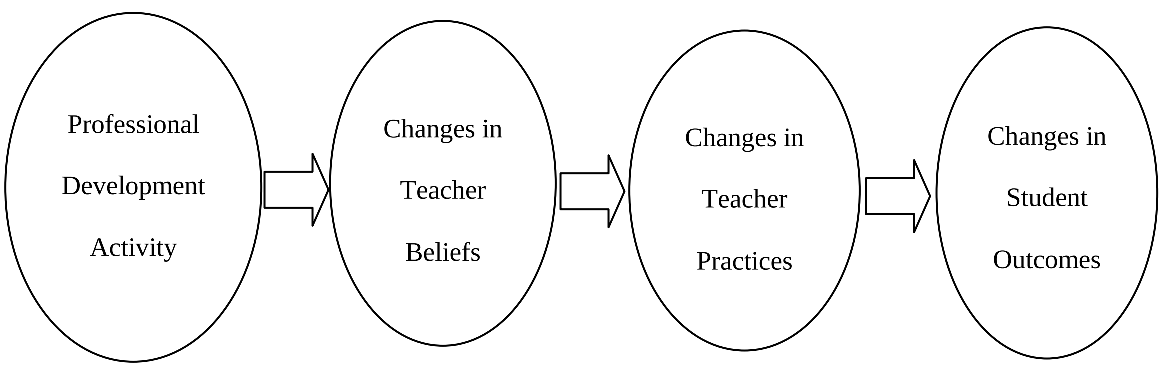

Figure 1: Representation of Guskey's (1985) description of the teacher change model assumed in traditional professional development.

This design for professional development was based on early models of teacher change which grew from a psychotherapeutic model (e.g. Lewin, 1935). However, in addition to failing to bring about change, this model of teacher change fails to account for existing data. Bolster (1983) and Crandall (1983) found that teachers became convinced in the effectiveness of new practices only after they felt that those practices had actually 'worked' in the classroom. Just prior to proposing his new model of teacher change, Guskey (1984) examined the changes in the beliefs and practices of a large group of teachers participating in a professional development program designed for implementation of a reform-based pedagogy. Most of the teachers implemented the new instructional strategy, but some did not. Of those that did implement, many felt they observed improved student outcomes while others did not. Guskey found that changes in beliefs only occurred with teachers who tried the new practice AND felt that they observed improved outcomes as a result. The beliefs of the teachers who did not experiment with the new strategies or who experimented with the new strategies but did not perceive improved student outcomes remained unchanged. Guskey (1985) argued that these findings provide clear evidence that the psychotherapeutic model of change was inaccurate. Guskey’s 1985 model reordered the sequence of the three major outcomes (see Figure 2). He proposed that teachers must first change their practice, and then observe positive changes in student outcomes which will only then ultimately cause changes in teacher beliefs. Guskey’s model has provided a theoretical framework for several researchers investigating teacher change (e. g. Mewborn, 2000; Breyfogle, 2005).

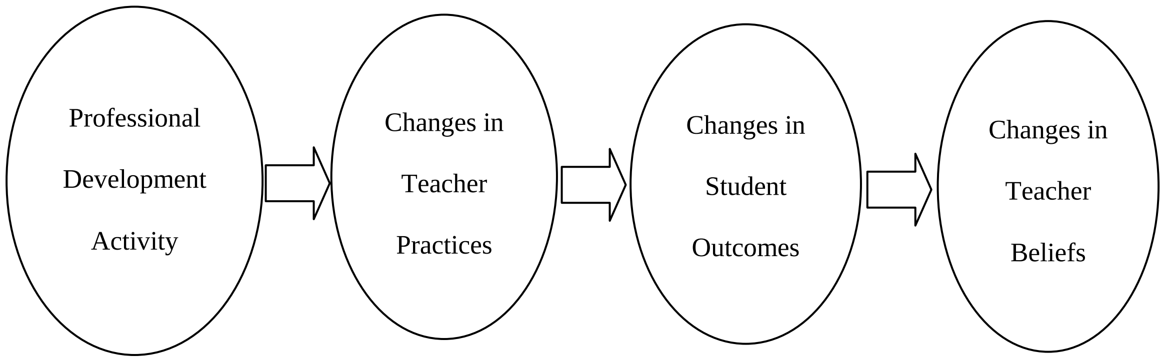

Figure 2: Guskey’s (1985) model of teacher change (p. 58).

There are two important notes about Guskey’s model. Though the model appeared to be linear, Guskey indicated that changes in a teacher’s beliefs occurred slowly over time and as a result of repeated positive experiences with new practices. Guskey had already started to recognize the cyclical interaction between beliefs and practices. The second important component of Guskey’s model resulted directly from his research observations. Guskey offered the caveat that ‘improved student outcomes’ was defined as being whatever evidence teachers used to judge if their teaching had been effective (Guskey, 1985). Teachers' beliefs might change only after the teacher perceived improved student outcomes which were due, in the teacher’s opinion, to the instructional changes. In light of the accepted view that beliefs impact perception as well as behavior, Guskey’s definition of ‘improved student outcomes’ becomes critical. Due to this impact on perception, a teacher might not recognize ‘positive’ student outcomes as being ‘positive’ or the teacher might not attribute those outcomes to the new practice. For example, if a teacher defined a controlled, quiet classroom as a ‘positive’ outcome of practice, then a reform-based pedagogy which encouraged student to student dialogue could be deemed inherently ineffective. While traditional, teacher directed pedagogy would be deemed effective. This first attempt to model teacher change helped reveal the importance of reflection, the cyclical interaction between beliefs and practices, the need to test out new practices, teachers' perception of effective teaching, and teachers' ability to observe student outcomes.

Breyfogle's addition to Guskey's model. Breyfogle (2005) utilized Guskey's model of teacher change to analyze one teacher's experiences as he tried to implement inquiry-based pedagogy in his classroom. Breyfogle's findings provided support for Guskey's model while also emphasizing the importance of reflection as has been intoned by several other researchers (e.g. Philipp, 2007; Thompson, 1984; Wilson & Cooney, 2002). Breyfogle built on Guskey's model by examining and emphasizing the impact that reflection can have on teacher change (see Figure 3). As discussed in the literature review, Tobin & Jakubowski (1992) proposed a schema of six cognitive requisites. For teacher change to occur, teachers must: (a) be uneasy with the way things are; (b) recognize that improvement requires change; (c) be committed to initiating change; (d) have a vision of the intended practice; (e) be able to visualize those changes in the classroom and reflect as they are taking place; and (f) have the opportunity to reflect on and questions their own practice. Breyfogle utilized videotaped lessons to help provide the required uneasiness with the status quo. These videos also created the opportunity for visualization, reflection, and questioning of one's own practice. In addition to incorporating Tobin and Jakubowski's cognitive requisites for change into Guskey's model, Breyfogle also highlighted the interaction between reflective states and reflective activities.

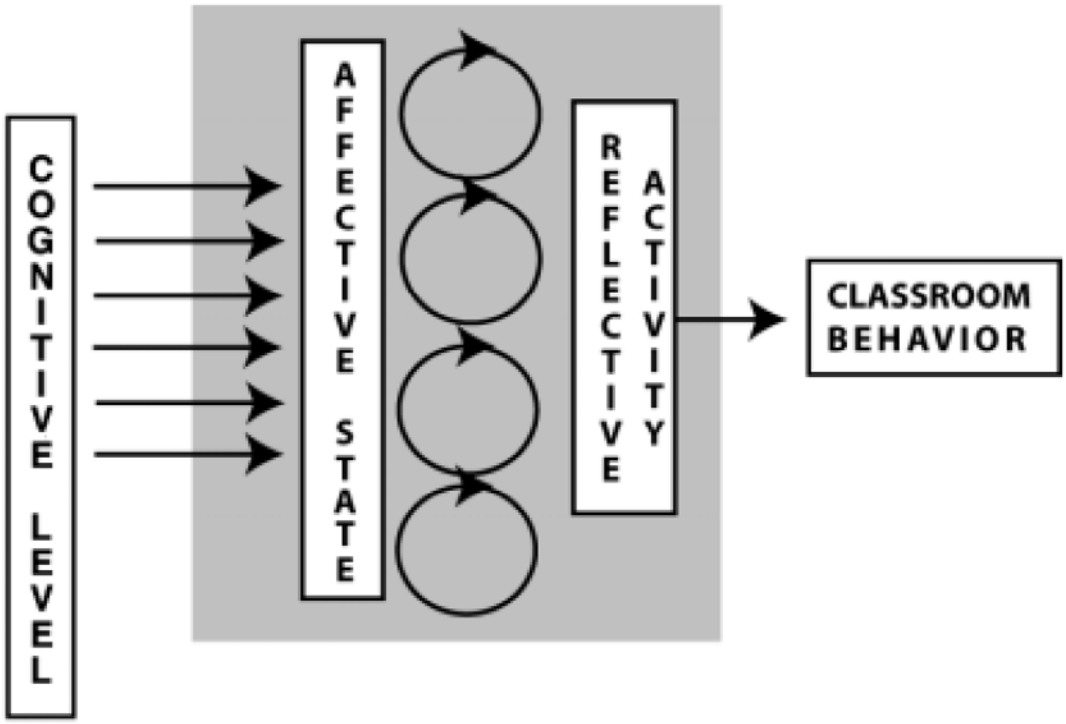

Figure 3: Breyfogle's (2005) addition to Guskey's model indicating the impact of affective states on reflection (p. 164).

Breyfogle argued that the teacher's attitude while engaging in reflection and the type of reflective activity interacted with each other to alter the impact on the teacher's practices. Breyfogle argued that the degree to which teachers reach Tobin and Jakubowski's levels of cognitive readiness is dependent on the teacher's reflective states as well as the reflective activity. Breyfogle claimed that teachers engage in reflective activities while in one of the following four reflective states: 'explain but not question', 'question but not explain', 'question and explore', and 'exploring'. Breyfogle argued that a teacher's reflective state would interact with the reflective activity to create the teacher's level of cognitive readiness. Though Breyfogle's assertion were based on only one participant's experiences, this work helped emphasize the impact on reflection played by focusing on student thinking, reflective activities, and teachers' affective states. The significance of teachers' affective states was emphasized by Philipp in 2007 along with the call for more research focused on teacher affect.

Ross & Bruce

In 2007, Ross and Bruce (2007a) developed a model for teacher change which they used in their study of an eighth grade mathematics teacher. The model (see Figure 4 below) was based on the key role that teacher self-assessment plays in teacher change. That same year, Ross and Bruce (2007b) used that model to guide their investigation of a professional development program specifically designed to improve teacher efficacy. Teacher efficacy is a teacher's expectation to have the ability to positively impact student learning, and it correlates with student achievement (e.g. Goddard, Hoy, & Woolfolk Hoy, 2004; Ross, 1998). Ross & Bruce asserted that teacher efficacy relates to increased student achievement because teachers with high efficacy are more likely to experiment with new innovative instructional practices (Ross, 1998), support student autonomy (Woolfolk, Rosoff, & Hoy, 1990), attend closely to students who appear weaker (Ashton, Webb, & Doda, 1983), and helps improve students' perceptions of their own ability. Since teacher self-assessment so heavily influences self efficacy, Ross and Bruce (2007a) designed a self-assessment tool to help guide participants as they observed their effect on student achievement, judged their attainment of their instructional goals, and reflected on their satisfaction. They designed their model to account for the relationships which they had observed between teacher efficacy, instructional practices, and student achievement.

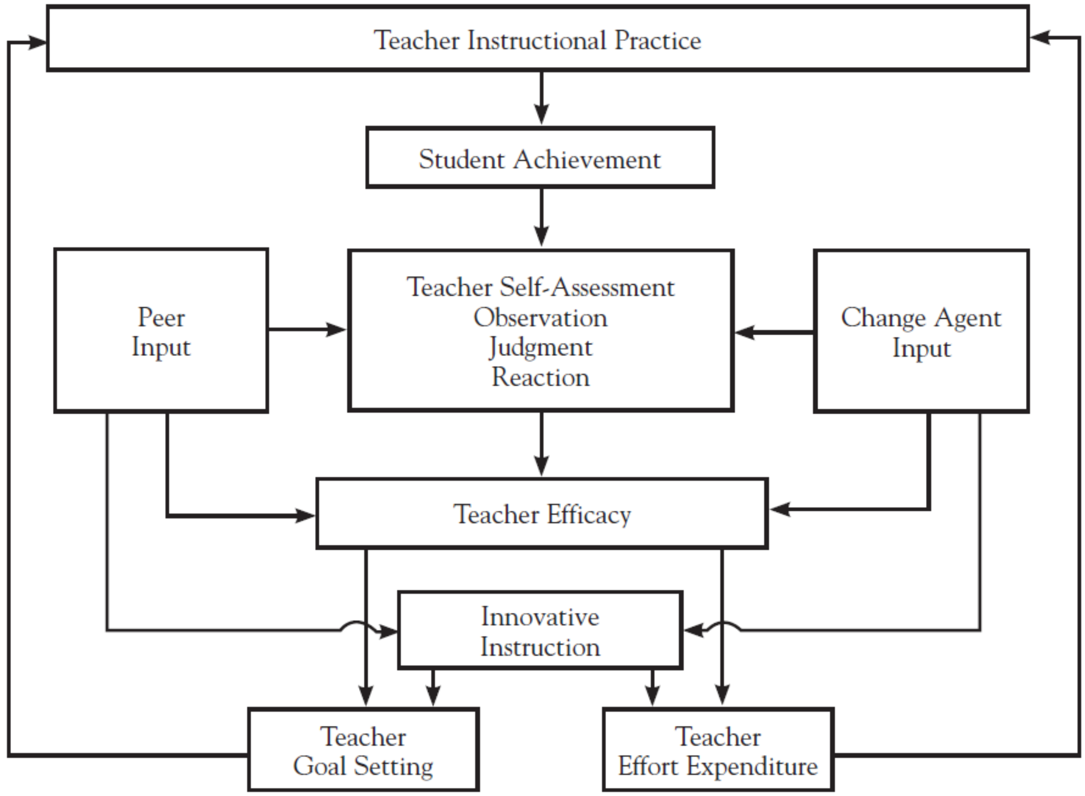

Figure 4: Ross & Bruce's (2007b) Model of teacher self-assessment as a mechanism for teacher change (p. 51).

Teacher self-assessment is at the heart of this model. Self-assessment was found to be influenced by peer and change agent input as illustrated in the model. The model also depicts that changes in goals and effort impact instructional practice which in turn impacts student achievement. In this way, Ross and Bruce have built onto Guskey's model by adding specificity, in ways similar to Breyfogle's addition of reflective states, to the reflection process. However, a key aspect to this model is the representation of the cyclical nature of the relationship between teacher practice, student achievement, reflection, and efficacy which is a type of teacher belief. This cyclical relationship, though, had not been depicted by previous models of teacher change. The cyclical nature of the relation between beliefs and practices, though discussed by Guskey and Breyfogle and agreed upon by many prevalent researchers in the field (e. g. Lerman, 2002), had not been depicted in previous models of teacher change. Like Breyfogle, Ross and Bruce highlighted the importance of reflection which researchers have indicated as critical to teacher change (e. g. Philipp, 2007). This model's focus on teacher self-assessment could help explain why multiple studies have found that training teachers to learn about student thinking has promoted changes in teacher beliefs (e. g. Ambrose, 2004; Philipp, 2007). However, there are other issues which researchers have shown are also critical to teacher change which were not depicted in this model.

Wilkins

A critical factor in teacher change that was not represented by the Ross and Bruce model is the key role played by teacher beliefs. As has been discussed at length, teacher beliefs have been found to be consistent indicators of practice. However, Ross and Bruce did not have access to a 2008 quantitative study which investigated the relationship between teachers' beliefs and practices. Ross and Bruce focused on teacher efficacy, a specific type of teacher belief, as the central component of their model instead of teacher beliefs in general. Teacher efficacy was the focus of research conducted by Ross and Bruce which placed the emphasis on teacher efficacy. But when modeling teacher change, it is more accurate for teacher beliefs to be at the core of the model. Wilkins' (2008) study represents one of the only quantitative investigations of teacher beliefs and practices.

Wilkins tested a theoretical model (see Figure 5 below) of the inter-relationship between knowledge, attitudes, beliefs, and practices using quantitative data from 481 in-service K-5 mathematics teachers. Inquiry-based teaching methods were the specific teacher practices being investigated. Wilkins based the theoretical model on Ernest's 1989 contention that a teacher's belief system is comprised of beliefs about mathematics as a subject, beliefs about teaching mathematics, and beliefs about learning mathematics. The model reflected the consistent findings that instructional practices are influenced by teacher knowledge (e. g. Fennema & Franke, 1992), attitude toward mathematics (e. g. Richardson, 1996), and beliefs about mathematics and mathematics instruction (e. g. Thompson 1992). Wilkins also considered the potential for teachers' background characteristics to relate to attitudes, knowledge, or beliefs. Based on the theoretical model, Wilkins conducted pathway analysis to test for the effect of each variable on variance in instructional practice.

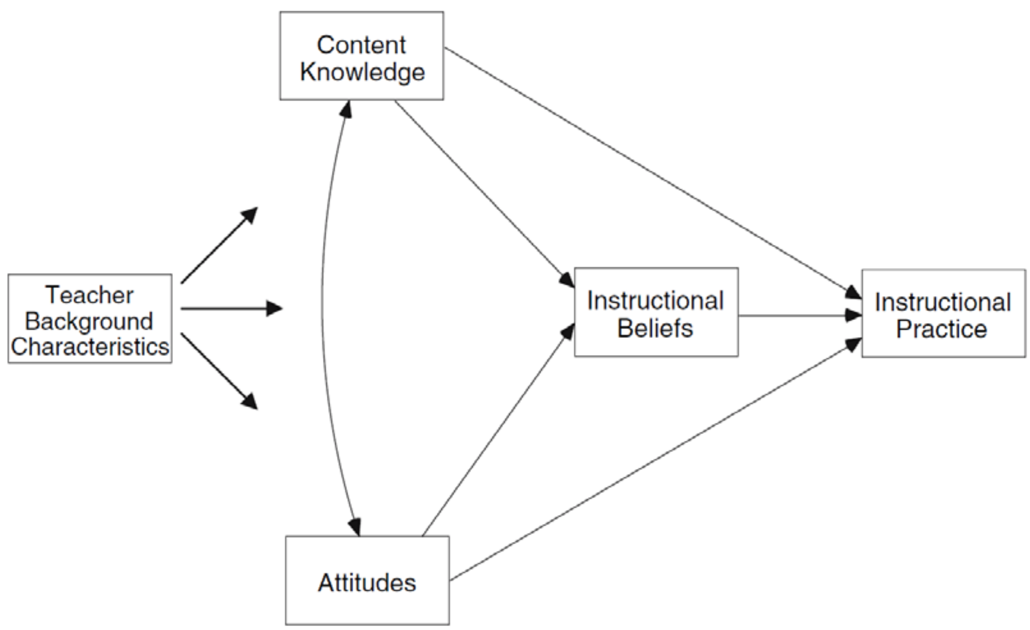

Figure 5: Wilkins' theoretical model of the relationship between knowledge, attitudes, beliefs, & practices (Wilkins, 2008, p. 145).

Wilkins found that the theoretical model was a viable representation of the relationship between teacher knowledge, attitudes, beliefs, and practice. Teacher background characteristics had no direct effect on instructional practice but had indirect effects that were mediated by content knowledge and attitudes. Teacher knowledge, attitudes, and beliefs were all found to have a direct effect on instructional practices, with beliefs having the strongest direct effect. Moreover, the effects of knowledge and attitude on instructional practice were found to be mediated by beliefs. Wilkins concluded that "not only were beliefs found to have the strongest direct effect on instructional practice but they also played a role in mediating the effects of teachers' knowledge and attitudes" (p. 156). The importance of beliefs found by Wilkins provided important support for the preponderance of qualitative research which has consistently highlighted the role that understanding teacher beliefs plays in understanding teacher practices.

Contextual Factors

Throughout the literature, researchers have found that teachers' beliefs and practices have been inextricably influenced by sociocultural factors. In the 1986 *Handbook of Research on Teaching*, Brophy & Good acknowledged that "effective instruction (even if attention is restricted to achievement as the sole outcome of interest) varies with context" (p. 370). Some of these contextual factors are located within the school, while other influences originate from the local communities and national cultures. A teacher's beliefs will be influenced throughout the teacher's experiences as a student, as a pre-service teacher, and as an in-service professional. Culture is inherently embedded in teaching (Hiebert & Stigler, 2000), and educational practices cannot be separated from the sociocultural environment in which those practices have developed (Alexander, 2001). It has become imperative for researchers to recognize the situated nature of teachers' beliefs and practices (Swan, 2004). Research into these contextual factors has occurred from a variety of perspectives. The research discussed below is only a representative sample of findings that have revealed the various ways in which contextual factors impact teacher beliefs and practices.

Culture impacts achievement. One consistent finding has been that student achievement, which is intricately linked to teacher beliefs and practices, varies with culture. When studying the development of cognitive arithmetic, Campbell and Xue (2001) concluded that cultural differences could account for differences in performance. East Asian students have consistently developed stronger numerical and arithmetic skills that their U.S. counterparts, though that advantage has not been found in other areas (Campbell & Xue, 2001). Most East Asian cultures rely heavily on examinations which are viewed as opportunities to cultivate competition, adaptation, endurance, and perseverance (Cheah, 1998). More recently, Tatsuoka, Corter, & Tatsuoka, (2004), found that culture could help explain patterns in countries' achievement profiles. Leung, Yung, and Tso (2005) found compelling evidence that achievement is higher in cultures where teachers feel appreciated by society. Singapore and Finland have performed consistently well on international assessments. In Singapore, teachers' salaries and status are relatively higher that U. S. teachers (Birenbaum, Tatsuoka, & Xin, 2005), and educators are highly regarded and respected in Finland (Bjorkqvist, 2005).

Researchers have found that culturally bound parenting differences can explain differences in achievement. Though a consensus has been established in the U.S.

regarding the important ways in which parents can positively impact literacy development in children, no such consensus exists for numerical development (Huntsinger, Jose, Larson, Krieg, & Shaligram, 2000). Huntsinger et al. (2000) compared the parenting practices of second generation Chinese Americans living in the U. S. to the parenting practices of multi-generational European Americans. The researchers found that European American parents interacted with their children in ways that reflected a Piagetian view toward developmental readiness and an evident value of self-esteem. While Chinese American parents tended to provide formal mathematics instruction to their children. When the first round of tests were administered at age 5 or 6, the mathematics achievement of children of Chinese American parents was higher than that of European American children. These cultural parenting differences predicted student achievement over a period of 4 years with the achievement gap increasingly steadily through all 3 test administration. Interestingly, European American children outscored Chinese American children on the English portion of the first assessment, but Chinese American students, despite English being the second language used at home, outscored European American children on the second and third tests. Chinese American parents also held stronger beliefs about the importance of their children liking and having success in mathematics (Huntsinger, Jose, Liaw, & Ching, 1997) which has also been shown to predict higher achievement (e. g. Galper, Wigfield, & Seefeldt, 1997). This study demonstrates the ways in which cultural differences at home can influence educational practices and achievement, but cultural factors can extend their influence into the classroom, school, and educational system in general.

Culture impacts practices. After analyzing the 1995 TIMSS data, Schmidt et al. (1996) concluded that “Countries have developed their own ways of engaging students in the substance of mathematics and science. There appear to be strong cultural components, even national ideologies, in the teaching of these subjects” (p. 132). Instructional differences between countries can be traced to differences in the cultures of those countries. Finland’s strong performance on the PISA has been due, in part, to having the smallest score distribution (Bjorkqvist, 2005). The practices adopted by Finish teachers to integrate students with special needs appear to have contributed to this small distribution Bjorkqvist, 2005).

There are multiple differences between the U. S. educational culture and the cultures in Europe and Asian. Stigler, Gallimore, and Hiebert (2000) found that U.S., German, and Japanese teachers used consistent scripts when teaching and these practices were significantly different between these three nations. U.S. teachers, who tend to adopt a Piagetian perspective, view cognitive development as independent from education, while Russian teachers, influenced by Vygotsky, have the view that development is dependent on teacher intervention (Alexander, 2001). Japanese teachers orchestrate lessons to expose primary children to key concepts in informal ways in order to prepare them for more rigorous study in secondary school while U.S. teachers prolong exposure to basic mathematics and science topics (Schmidt et al., 1996). In Europe, curriculum is a subset of pedagogy, but the reverse is the case in the U. S. (Alexander, 2001). U. S. Policy makers have become convinced by research findings indicating that East Asian cultural values strongly impact East Asian instructional practices (LeTendre, Baker, Akiba, Goesling, & Wiseman, 2001). The recent Common Core initiative in the US reflects the apparent success of East Asian countries' reliance on national curricula while various standards are used throughout Europe. In an effort to insure a healthy 21st century economy, the Singaporean government created an educational slogan to guide educational reform: 'Thinking schools—learning nation' (Birenbaum, Tatsuoka, & Xin, 2005). However, the Swiss educational culture is modeled on communities. The school system focuses on school autonomy and involves community parents and classroom teachers to make educational decisions (Schmidt et al., 1996). However, pedagogical methods that appear to work in one culture might not work in another culture and could in fact disrupt educational practices due to those cultural differences (Alexander, 2001; Hiebert & Stigler, 2000).

The factors which influence the beliefs and practices of teachers have been researched at length. Though current models incorporate some of these findings, researchers have yet to develop a model which incorporates all of these components while also accounting for current findings on teacher change. Guskey (1984), Ross & Bruce (2007a, 2007b), Wilkins (2008), and many others have made important contributions, but these models fail to represent the importance of teacher beliefs, the interaction between teacher beliefs and various professional activities, or the impact of contextual factors. And no current model accounts for both sociological and psychological views toward teacher change. In 2006, Llinares and Krainer summarized the call for more accurate modeling of teacher change; "If we regard a teachers' professional development as a learning process, we must create a model of how we understand this learning process and the factors that influence it" (p. 445). Below follows the proposal of a new model for teacher change which was created based on the research, theory, and models reviewed above to guide and frame the current study. This proposed model is also offered as an answer to the call quoted above.

The Contextualized Interaction Model of Teacher Change

There are four key aspects to the model: a) the central role played by beliefs, b) five types of professional activities, c) the interactive relationship between beliefs and professional activities, and d) the contextual factors which influence these interactions. The *Contextualized Interaction Model* of teacher change is presented in Figure 6 below. A discussion of the model components follows.

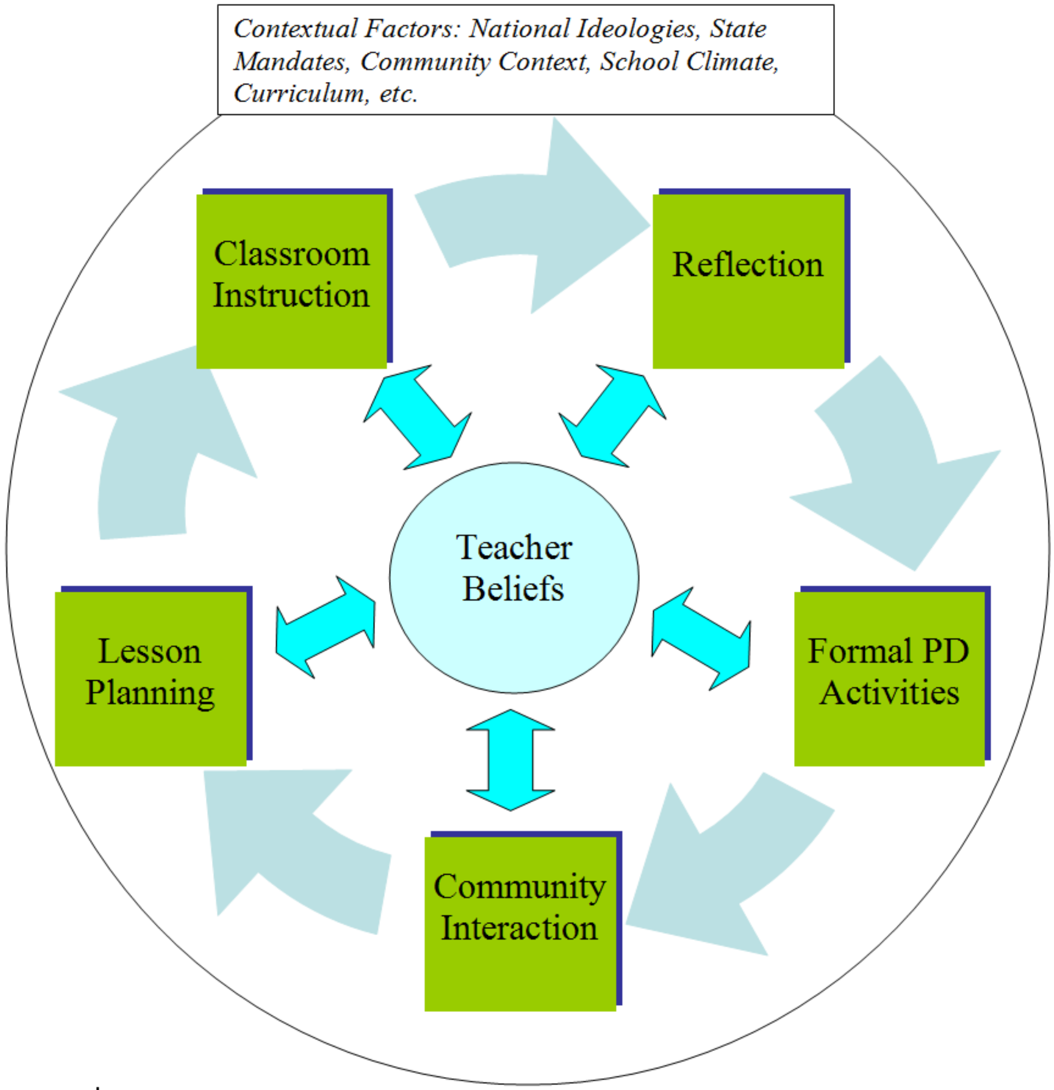

Figure 6: The *Contextualized Interaction Model* for teacher change proposed by Henry W. Neale, Jr. 2011

Teacher beliefs. As has been found by repeated studies (e. g. Wilkins, 2008) teacher beliefs, in particular beliefs towards mathematics as a subject, have consistently correlated with classroom practices. Moreover, teacher knowledge, which falls under the heading of teacher beliefs for this model, has also consistently correlated with teacher practices and growth. Beliefs have also been shown to be strongly influenced by sociocultural factors. Additionally, teacher beliefs and knowledge represent a variable which can only be measured indirectly while the other model components can all be measured directly. For these reasons, beliefs lie at the center of the model.

Professional activities. The professional activities in which teachers engage can occur in a variety of forms. The model represents 5 different types of professional activities which impact each other in a cyclical fashion. Researchers have repeatedly referenced lesson planning, classroom instructional practices, and school-based reflection on instructional practices as important components of teachers' professional activities, and the model presents these 3 forms of activity in the typical cycle. Professional development can occur in formal and informal ways and can occur off campus or be school-based. Finally, teachers frequently engage in social interaction within the community as professionals. This social interaction can occur in formal educational events as well as informal encounters on and off campus. These various scenarios are represented by formal professional development activities and social interaction. It's important to differentiate professional activities in which teachers engage with other professionals as opposed to situations in which teachers interact with community members. For these reasons, the professional activities in which teachers could engage have been separated into the five components of lesson planning, classroom instruction, reflection, formal professional development activities, and social interaction. However, it is very important to note that this model represents the forms of professional activities which have the potential to mediate teacher change. Teachers may or may not engage in lesson planning, reflection, formal professional development activities, or social interaction as a professional. This model would subsequently predict few opportunities for teacher change for those teachers. Also, formal PD activities appear prior to social interaction in the model strictly for convenience. The model does not intend a specific order but rather represents the cyclical nature of the impact that each form of professional activity can have on the other forms.

Interactive relationships. As discussed, research has verified theorists' claim concerning the interactive nature of the relationship between beliefs and behaviors. Researchers have found that real changes in beliefs and behaviors accompany each other. This interactive relationship is represented by the bi-directional arrows between beliefs and the 5 forms of professional activities. Beliefs impact teacher perception of and participation in those activities, and the ways in which a teacher participates in those activities will in turn impact that teacher's beliefs. These interactive relationships are represented using double arrows between the professional activities and teacher beliefs in part to represent the inability of researchers to measure this interaction directly.

Contextual factors. The final key factor represented in this model of teacher change is the role played by various contextual factors. The large circle encompassing teacher activities, teacher beliefs, and the interaction between beliefs and practices represents the role played by these factors. Teacher engagement in professional activities only occurs within these contexts. The formation of teacher beliefs is similarly contextualized as well. And perhaps most importantly, these contextual factors will inevitably impact the interaction between beliefs and practices. Worldwide standards, national ideologies, national and state curricula, community influences, school-based decisions, peer collaboration, and student interaction have the potential to impact teacher practices. In the sociocultural constructivist tradition, teachers' beliefs are formed and teachers act only within a sociocultural context. And how teachers participate in professional activities plays a critical role in the sociocultural development of education.

The *Contextualized Interaction Model* for teacher change can be used to impact examinations of teacher change and the design of professional development. The remainder of the theoretical framework will include a discussion of the impact on the design of professional development along with a model-driven analysis of the keys to effective professional development. A general discussion of the model's impact on studying teacher change will then be provided followed by a description of the model's influence on the current study.

Effective Professional Development

Based on the *Contextualized Interaction (CI) Model* of teacher change, effective professional development (PD) would engage teachers in all 5 forms of professional activity. Most PD continues to occur in the form of workshops sessions (Meyer, 2005). This common form of PD utilizes only one type of professional activity with designers hoping for transference from the workshop to lesson planning, instruction, and reflection with few PD programs including any social interaction form of professional activity. The *CI Model* helps explain why the typical form of PD in the U. S. has been largely ineffective (e. g. Guskey, 2002a). Most teachers in the U. S. believe that they implement reform-based pedagogy but in fact fail to do so (Meyer, 2005). Teachers need direct experience with the new practices targeted by PD programs. Teachers also need to learn how to plan lessons that accurately reflect program goals. Polly (2009) found that lessons which were co-planned with teachers were implemented with greater fidelity to program goals than lessons adopted directly from PD sessions. Teachers also need to know how to reflect on their classroom instruction to determine if the lesson goals were achieved. Reflection is considered by many to be the key to changing teacher practices (e. g. Llinares & Krainer, 2006; Philipp, 2007). But PD goals could be derailed by teachers' evaluation of lesson effectiveness using weak data and/or weak collection methods.

The interactive relationship between beliefs and practices should also be utilized by PD designers. Teachers need to become aware of how their teaching practices relate to their beliefs about the content of mathematics, learning mathematics, and teaching mathematics (see Leder, Pehkonen, & Torner, 2002; Swan, in press; Wilkins, 2008). Researchers (see Thompson, 1984; Breyfogle, 2005; Philipp, 2007; Polly, 2009) have repeatedly noted inconsistencies between teachers' beliefs and practices. Designers should help teachers learn how to examine their practices to determine the degree to which they coincide with their beliefs.

Lastly, the sociocultural environment in which teachers are being asked to develop must also be considered. Inconsistencies between beliefs and practices are often due to contextual factors. In general, reform-based pedagogy and curricula will not align well with contextual factors in the United States. Teachers will encounter political and cultural barriers (Johnson, 2006), and many schools lack the organizational structure required to support teachers' efforts to learn from classroom experiences (Hiebert, Morris, & Glass, 2003). Teachers trying to implement these pedagogy and curricula require special training to insure positive engagement with the community in addition to needing specific administrative support. For example, Swan (2004, in press) found that community and school-based contextual factors influenced teachers' implementation of student-centered teaching practices. Similarly, Hiebert and Stigler (2000) noted one teacher's failed attempt to implement a problem-solving lesson. The students expected to be shown and told what to do, and the lesson differed too greatly from this system to be accepted by the students.

Designers can make PD more effective by including every aspect of the *CI Model*. For example, *Lesson Study* has been examined as a particularly effective form of PD (see Fernandez, 2005; Hiebert & Stigler, 2000). *Lesson Study* is utilized in Japanese elementary school but has been adopted in some U. S. schools (Meyer, 2005). *Lesson Study*, as described by Fernandez (2010), is a form of professional development which is highly valued by Japanese teachers. The process includes the collaborative design and investigation of a research lesson. The process includes cycles of collaborative planning, collaborative lesson observations which include observers from beyond the school, thorough reflection on the research lessons, and continued lesson revision. Hiebert and Stigler (2000) argued that Japan's performance on *TIMSS* and *PISA* attests to the success of *Lesson Study*. More recently teachers' participation in *Lesson Study* was found to lead to changes in beliefs (Fernandez, 2005) and changes in practice and improved knowledge (Meyer, 2005). However, an analysis of *Lesson Study* using the *CI Model* of teacher change can help explain this success. *Lesson Study* engages teachers in all 5 forms of professional activity while also deliberately incorporating social interaction. When utilized in the U. S., the problem-solving focus of *Lesson Study* requires teachers to deliberately question their beliefs about the content of mathematics, teaching mathematics, and learning mathematics while also requiring teachers to try out different practices in the classroom. Another sociocultural benefit of this form of PD is that group participation leads to improved teacher efficacy (Hiebert & Stigler, 2000) which is helpful when implementing new practices (Wilkins, 2008). In addition to reflection playing a key role in *Lesson Study*, lesson effectiveness is evaluated based on the attainment of student learning goals which helps convince teachers of the benefits of using reform-based pedagogy. Previous models of teacher change have failed to account for the various reasons why *Lesson Study* would be an effective form of PD.

Studying Teacher Change using the CI Model

The *CI Model* has applications to the general study of teacher change, whether the research focus is teacher practice, teacher beliefs, teacher knowledge, or sociocultural in nature. For example, if teacher knowledge is the topic of interest, the model illustrates the potential impact on teacher knowledge of teacher beliefs, the interaction with practice, and sociocultural factors. Research which examines teacher knowledge without considering the sociocultural context or without examining the relationship between teacher knowledge and beliefs and practice will provide an incomplete picture. It would be easy to conclude, as was the case in the 60's and 70's, that there is no relationship between teacher knowledge and student achievement when in fact, as Wilkins (2008) found, teacher beliefs can mediate teacher knowledge and relate more strongly to practice that knowledge. And of course, if student achievement is measured by performance on a state test but teacher knowledge is measured against different standards, then there would be little reason to assume a correlation between the two. Similarly, if the relationship between teacher practices and beliefs is examined without consideration of contextual factors, then researchers (e. g. Hoyles, 1992) could be led to conclude that practices are inconsistent with beliefs when, as Skott (2001) argued, the practices only appeared inconsistent with beliefs because teacher motivations are context dependent (Philipp, 2007).

These examples have of course been available to researchers to quite some time, but the *CI Model* provides the first visual representation of these relationships. Researchers investigating teacher knowledge, beliefs, practices, or contextual factors could use the model to insure that all important factors were considered. For the current study, the model was used to help formulate and explore the research questions. There were two key arenas which influenced the current study: Hiebert, Morris, and Glass' (2003) experiment model for teaching and *Cognitively Guided Instruction*. Hiebert, Morris, and Glass developed a teacher preparation program which focused on improving teacher practice through lesson design, reflection, and the creation of a knowledge base for teachers. The authors aimed to train pre-service teachers to "design lessons with clear goals in mind, monitor their implementation, collect feedback, and interpret the feedback in order to revise and improve future practice" (p. 206). The idea behind this program was that teachers, to grow generatively, need to learn how to plan lessons around clear goals and then use data to determine the effectiveness of the implementation of that lesson plan. Teachers engaged in formal PD to work toward obtaining mathematical proficiency as defined by the NRC (2001). This framework shares some components with *Lesson Study* and relates to 4 forms of professional activity from the *CI Model* while also focusing on the interaction between beliefs and practices. Hiebert, Morris, and Glass recognized that teachers need to 'test out' practices which might not coincide with their beliefs while also using strong data to determine the effectiveness of those practices. The authors identified student thinking as the critical measure of lesson effectiveness.

The CGI work of Fennema, Carpenter, Franke, and others began in the 90's and is still receiving attention due to the impact that focusing on student thinking appears to have on the beliefs and knowledge of teachers (e. g. Philipp, 2007). Hiebert, Morris, and Glass (2003) deliberately trained teachers to measure lesson effectiveness in terms of student thinking because of the richness of this data source and the apparent impact on beliefs and practices. Also, Franke, Carpenter, Levi, and Fennema (2001) found that engagement with CGI led to generative growth. Changing teachers' beliefs about the effectiveness of practices may hinge on student thinking as opposed to other measures. This potential relationship highlights the importance of reflection and the interaction between beliefs and practices as indicated by the *CI Model*.

Research questions. The research questions emerged from the literature discussed above and the creation of the *CI Model*. The current study is much too small to test the validity of this model in general. The study was also not intended to follow a grounded theory methodology. Rather, the model was used to help formulate research questions, guide investigation, and inform data collection and interpretation. The first research question was the obvious progression from the development of the model. An important reason the model was created was to provide a visual representation to help guide research into teacher beliefs, practices, and the contextual factors. The current study provides an example of one way in which the model can help guide researchers. Based on the model, since beliefs and practices interact in multiple areas of professional activity, then the degree to which a teacher's beliefs and practices change should be depend upon the ways in which the teacher engages in those activities. For example, if teachers consistently re-affirm their own beliefs while engaging in the different professional activities, then not only their beliefs and practices not change, but those views towards mathematics education will be subsequently propagated. However, if a teacher attempts to utilize practices which diverge from their own beliefs, then he or she might use those practices repeatedly if those divergent practices are perceived as more effective.

Hiebert, Morris, and Glass argued for the need to train teachers to implement lessons as experiments and to measure lesson effectiveness using student thinking. The work with CGI supports the notion that using student thinking to measure lesson effectiveness can result in changes in the beliefs and practices of teachers. The *CI Model* helps explain why the key to changing the beliefs and practices of teachers could be the combination of viewing lessons as experiments and measuring lesson effectiveness in terms of student thinking. As illustrated by the *CI Model*, the interaction between beliefs and practices and the cyclical nature of teachers' professional activities would predict that changes in a teacher's beliefs and practices would only occur over time after repeated cycles. But for teacher change to occur, the teachers engagement in these professional activities would have to conflict with their beliefs. The second and far more significant research question emerged from the hypothesis that for a teacher's beliefs and practices to change, that teacher would have to implement instruction practices which challenged their beliefs while also concluding that those instructional changes resulted in positive outcomes.

Developed from the preceding review of the literature, the degree to which a teacher possesses an experimental view toward teaching was hypothesized as a key predictor of teacher change. The concept of an experimental view represented the combined views of Hiebert, Morris, and Glass' experiment model for teaching and the findings from the CGI studies. For a teacher to have an experimental view toward teaching, that teacher would 1) Be motivated, through a desire to grow professionally, to implement divergent instructional practices, 2) Implement instructional practices that challenged beliefs, and 3) Focus on students' mathematical thinking as the key measure of lesson effectiveness. Teacher motivation to grow professionally was considered a key component because research and theory have revealed that beliefs can be resistant to change in part because beliefs impact perception. Teachers must be motivated to challenge their beliefs and practices for either to change. The implementation of instructional practices which diverged from existing beliefs and practices emerged from Guskey's theories to become a key component. Guskey hypothesized that beliefs only changed after a teacher tested divergent practices and also concluded that those divergent practices resulted in positive outcomes. This idea of divergent practices being reinforced by the perception of positive outcomes led to the third component. However, this view of reinforcing certain instructional changes depends heavily on how a teacher chooses to evaluate lesson effectiveness. Since student outcomes should be the key measure of instructional effectiveness and due to the findings from the CGI research, a focus on student thinking was identified as critical.

The *CI Model* was developed in concert with efforts to understand why having an experimental view would result in teacher change. Even though the development of the *CI Model* was initially ancillary to the investigation into the significance of viewing lessons as experiments, the development of a more accurate and more encompassing model of teacher change may represent the greater contribution of this study. The model not only provided a framework for understanding teacher change and the impact of having an experimental view, but the model also helped explain why some professional development programs may be more effective than others. Additionally, the *CI Model* helped guide the methodology for the study. The model revealed the need to observe instructional practices, lesson planning, and reflection while also collecting data on teacher beliefs, practices, and knowledge. The next chapter reviews this methodology.

CHAPTER 4: METHODOLOGY

Participants

Participants for the study were obtained from a group of 26 K-4 teachers from a small school district in the southeast. These 26 study candidates were engaged in a system-wide professional development program on which the author was a co-investigator. The teachers engaged in the program worked at five different elementary schools. All five participating schools were Title 1 schools with approximately 70% of the students qualifying for free and reduced lunch. Over 70% of the students in the two participating schools qualified for free and reduced lunch. Of the 26 teachers engaged in the professional development program, 7 were male and 19 were female. The teachers had been nominated for the program by their respective principals. Principals were asked to select teachers who could act as educational leaders within their school. Below follows a description of how the three study participants were obtained from this group of candidates.

All 26 candidates, as participants in the professional development program, completed a teacher knowledge test, a teacher beliefs survey, and a teacher practices survey prior to participating in any professional development activities. These instruments were used as a pre-test to track changes in the knowledge, beliefs, and practices of the teachers participating in the program. The data from these pre-tests were used to identify potential participants for this study. As discussed in the literature review and predicted by the *CI Model*, differences in teacher knowledge and contextual factors may impact changes in teachers' beliefs. The goal of the study was to determine the ways in which the *CI Model* and having an experimental view toward teaching helped explained and account for changes in teacher beliefs. The following criteria were used to minimize the impact of contextual factors while also seeking diversity in participants' beliefs. Since having an end of grade test was anticipated as being a significant contextual factor, only third and fourth grade teachers were included in the study. From this group of nine candidates, one was excluded due to significantly higher teacher knowledge test scores. The results of the beliefs survey were then used to identify candidates with different teacher beliefs. Differences in beliefs were identified using the Teacher Beliefs Survey (Appendix B). Teachers were identified as having beliefs which tended toward a transmissionist, discoveriest, or connectionist view toward mathematics, learning mathematics, and teaching mathematics. For the data from the knowledge test beliefs survey, and practices survey, see Table 1 in the Results Chapter.

From these nine potential candidates, just two teachers indicated a strong transmission orientation. Both of these teachers were invited to participate in the study, but both chose not to participate due to workload concerns. The teacher who showed the strongest connectionist orientation was invited to participate and accepted. He will be referred to by the pseudonym Alex for the remainder of the paper. The teacher who showed the strongest discoveriest orientation also accepted the invitation to participate in the study and will be referred to as Stephanie. A third participant was identified because her beliefs survey indicated absolutely no preference for any orientation but also because she taught the same grade level at the same school as Stephanie. Her pseudonym will be

Tracy. Due to these similarities in school environments, teacher knowledge, and gender, Stephanie and Tracy were considered ideal participants for the purposes of the study. Alex taught fourth grade at a different school but obtained a similar knowledge score. Since the two schools were similar in many ways and located in the same small city, many of the contextual factors should have been similar for all three participants. One major difference however, was that the fourth grade End of Grade Test determined whether or not students passed the fourth grade which was not the case in third grade. Based on the *CI Model*, the contextual factor of having an end of grade test represented an important difference between Alex and the other two participants.

Professional Development Program

All the participants were engaged in the same 2-year professional development program. The program began during the summer of 2009, continued throughout the school year, and another summer session began during the summer of 2010 at which point participants were asked to become professional development leaders for the next cohort. The participants received training aimed at improving instructional practices and increasing teacher knowledge. The program placed a focus on the *NCTM Standards* and reform-based teaching practices and emphasized the use of inquiry. The professional development program in which the teachers participated offered the teachers the opportunity to engage in reform-based lesson planning, instructional practices, and reflection.

During the first summer of professional development, teachers received training and practiced designing lessons based on the 5 *E*'s. The 5 *E*'s lesson plan includes the phases Engage, Explore, Explain, Extend/Elaborate, and Evaluate. The evaluate phase is focused on students and teachers evaluating their understanding of the learning objective. Extensive time was spent on improving teachers' use of inquiry throughout instruction, and teachers were provided with video examples of reform-based pedagogy being utilized in practice. One professional development session was committed to examining *Cognitively Guided Instruction* and providing instruction and examples of how to investigate and analyze student thinking.

The program continued throughout the year with participants meeting for six, three hour sessions every three to four months. The goals of these sessions varied depending on the needs expressed by participants and administrators. Additionally, professional development designers visited schools and met with teachers by grade level and individually to work on curriculum alignment, implementation, lesson planning, evaluation, and to support continued growth in teacher knowledge.

Data Collection

Instruments

Four instruments were used in this study. Participants took a Teacher Knowledge Assessment, the *Learning Mathematics for Teaching* tool (see Appendix A) developed at the University of Michigan to assess teachers' knowledge. Participants also took three surveys: a Beliefs Survey (Appendix B) designed by Swan (2004), a Practices Survey (Appendix C) also developed by Swan (2004), and a View Toward Teaching Survey (Appendix D) designed by the author for use in the study. The Teacher Knowledge Test, the Practices Survey, and the View toward Teaching Survey were administered using a pre-test/post-test design (see Table 1 for the data collection timeline). A repeated measures method was employed for the Beliefs Survey in order to track changes in beliefs over time.

The *Learning Mathematics for Teaching* assessment (Appendix A) was designed to indicate the depth to which elementary school teachers understand the mathematics that they are teaching. The assessment required teachers to analyze and interpret student errors and misconceptions along with a range of approaches to solving common problems in addition to reflecting teacher understanding of these topics. The instrument was specifically designed to determine the degree to which elementary teachers have the knowledge required to teach mathematics well. The assessment contained 62 questions and included measures of content knowledge, pedagogical knowledge, pedagogical content knowledge, and knowledge of student development. Each item was scored as a 1 for a correct answer and a 0 for an incorrect or no answer. The *Learning Mathematics for Teaching* assessment was selected because Hill, Rowan, and Ball (2005) had demonstrated that differences in teacher knowledge, as measured using this instrument, consistently related to gains in student achievement even after accounting for mediating factors. This instrument was also selected because Hill, Schilling, and Ball (2004) had already established the reliability using BILOG to fit initial item response theory models to their data. Their analysis revealed good to excellent (.71-.84) classical test theory measures of reliability for all domain scales. This instrument has been used in multiple other studies as well (see Gleason, 2010). Participants with similar teacher knowledge scores were selected to minimize differences in beliefs and practices due to differences in teacher knowledge. The instrument was also used to identify changes in teacher knowledge which might be attributable to differences in beliefs, contextual factors, or views toward teaching as opposed to initially different levels of teacher knowledge.

The Beliefs Survey (Appendix B) was developed by Swan (2004) using Ernest's (1991a, b) model of teacher beliefs. The instrument was designed to identify teachers' views toward mathematics as a subject of study, mathematics teaching, and mathematics learning. Swan (2004) categorized teachers' beliefs based on Askew, Brown, Rhodes, Johnson, and Wiliam's (1997) characterizations of teachers' orientations as *transmission*, *discovery*, or *connectionist*. Teachers' orientations toward mathematics as a subject of study, the teaching of mathematics, and the learning of mathematics were viewed as *transmission* if teachers tended to view mathematics as a collection of rules that teachers had to tell students. A *discovery* oriented teacher viewed mathematics as a human creation which students must discover through individual investigation. While a *connectionist* teacher viewed mathematics as a socially constructed network of ideas which students and teachers uncover but also construct through collaboration. These two instruments were selected in part because Swan (2004) had already established the validity and reliability of the Beliefs Survey and Practices Survey using triangulation between teachers' pen portraits of themselves, independent lesson observations, and student questionnaires.

The Practices Survey (Appendix C) was a 25 item Likert scale survey designed to determine the extent to which teachers reported the use of student-centered or teacher-centered practices. Participants indicated if they almost never, sometimes, half of the time, most of the time, or almost always utilized specific teaching methods in their classrooms. Each teaching method described was predetermined to represent a teacher-centered or student-centered practice. Of the 25 items, 12 represented student-centered practices while 13 represented teacher-centered practices. The responses were scored as follows: almost never = 1, sometimes = 2, half of the time = 3, most of the time = 4, or almost always = 5. Scores on the student-centered practices were averaged to determine each teacher's average tendency toward using student-centered practices. The same process was used to determine teachers' tendency toward using teacher-centered practices. The teacher beliefs and teacher practices surveys were also used, in part, because the reliability and validity of both instruments had already been checked utilizing teacher self-descriptions, classroom observations by independent researchers, and student questionnaires (Swan, 2004).

Finally, in addition to developing an interview protocol to determine the degree to which participants held an experimental view toward teaching, a View toward Teaching Survey (Appendix D) was designed to help address the secondary research question. This instrument contained questions which were similar to those in the interview protocol, but the survey was given to participants just prior to the interview. The participants completed the survey informally and on their own schedule. The instrument was used as a prompt and to help identify areas on which to focus interview questions. Since the main focus of the survey was to stimulate participant thinking toward issues dealing with the second research question, the reliability and validity of the instrument were not tested. The survey contained 12 Likert-scale items and 12 occurrence frequency items. Each item contained a statement which deliberately aligned or misaligned with an experimental view toward teaching. The items focused on desire to try differing practices, reflection, and measures of lesson effectiveness. Each item was scored as ±2, ±1, with a 0 as an option only for the Likert-scale items. Points were added or subtracted depending on alignment with an experimental view toward teaching; therefore, a maximum score of 48 points was possible if someone indicated maximum alignment with experimental view while a score of -48 would indicate complete misalignment. As the instrument was intended as a prompt for the participants and to help guide interview questions, no reliability or validity testing was completed on this instrument.

Timeline

Participants completed the knowledge assessment and beliefs and practices surveys during the first two days of the professional development summer workshop. The beliefs survey was administered a second time during the baseline interview along with the view toward teaching survey early in the fall of the study year. The knowledge assessment and beliefs and practices surveys were re-administered to participants again in late spring, and the beliefs survey was administered for the fourth and final time during the End of Study Interview during the second summer workshop. In addition to the four quantitative instruments, qualitative data were obtained from a variety of sources: videos, interviews, questionnaires, reflective essays, and submitted lesson plans. Teachers submitted reflective essays and complete lesson plans during both summer PD sessions and during the school year. Teachers were observed several times throughout the year often with pre- and/or post-observation interviews. An in-depth, formal Baseline Interview occurred at the beginning of the school year, and the End-of-Study Interview occurred during the summer after the end of the school year. Table 1 below provides a timeline for data collection along with a list of the purposes behind the use of each instrument which are discussed in the next section.

Table 1
Data Collection Timeline and Purposes

Timeline	Data Source/Instrument	Collection Purpose (Primary Sources in bold)
June	Learning Mathematics for Teaching Test	**Pre-test measure of teacher knowledge**
	Practices Survey	**Pre-test measures of teacher practices.**
	Beliefs Survey	**1st (Pre-test) measures of teacher beliefs.**
	Workshop Observation	Track Professional Development activities
	Workshop reflection	To determine initial reaction to PD experiences- degree to which beliefs were challenged by activities.
August	Workshop Observation	Track Professional Development activities
September	Baseline Interview	**Code interviews and align with *CI Model*** **Determine extent to which teacher possesses experimental view toward teaching.**
	Beliefs Survey	**2nd (Baseline) measure of teacher Beliefs**
		View toward Teaching survey Determine/confirm teacher beliefs towards mathematics, teaching, and learning.
		Introduce researcher to class.
October	Observation #1 + Interview	**Examine beliefs-practices inconsistencies**
		Examine alignment with experimental view
November	Observation #2 + Interview	Examine beliefs-practices inconsistencies
		Examine alignment with experimental view
January, 2010	Observation #3 + Interview	Examine beliefs-practices inconsistencies
		Examine alignment with experimental view
February	*Observation #4 + Interview	Examine beliefs-practices inconsistencies
	*As needed	Examine alignment with experimental view
March	*Observation #5 + Interview	Examine beliefs-practices inconsistencies
		Examine alignment with experimental view
April	*Observation #6 + Interview	Examine beliefs-practices inconsistencies
		Examine alignment with experimental view
May	Learning Mathematics for Teaching Test	**Post-Test measure of teacher knowledge**
	Practices Survey	**Post-Test measure of teacher practices**
	Beliefs Survey	**3rd (Post-Test) measure of teacher beliefs**
August	End-of-Study Interview	Determine overall reaction to PD experiences.
		Self-assessment of impact on beliefs
	Beliefs Survey	**4^{th} (End of Study) measure of teacher beliefs** **Track changes in teacher beliefs toward math, teaching, learning, and experimental view.**

Purpose and Analysis

Knowledge Assessment and Surveys

The teacher knowledge assessment was administered for three purposes. Initially, this assessment helped identify the participants from the set of candidates in an attempt to restrict the impact of differences in teacher knowledge on changes in beliefs. The knowledge assessment was also administered using a pre- and post-test design to identify changes in teacher knowledge that might relate to changes in beliefs. The knowledge test was also used to triangulate observational data and interview data which might suggest the impact of teacher knowledge on practices as has been found in other studies (see Da Ponte & Chapman, 2006; Ross & Bruce, 2007; Wilkins, 2008). The practices survey was administered along with the knowledge assessment to identify changes in practices and to help stimulate interview questions. Based on previous works (see Philipp, 2007), inconsistencies between participants' beliefs and practices was identified in advance as an issue connected to both research questions. In particular, the *CI Model* depicts the contextual factors that might help explain these inconsistencies. The practices survey was used in concert with the beliefs survey to triangulate observational and interview data to investigate this *a priori* theme. The beliefs survey was used to track changes in teacher beliefs over time and was administered four times over the course of 14 months using a repeated measures design. Lastly the view toward teaching survey, which was designed for this study, was used to obtain a general idea of the degree to which participants' held an experimental view toward teaching. However, the main purpose of the survey was to stimulate thinking for the baseline and end of study interviews.

The scores of the knowledge test were reported directly, so no analysis occurred. However, for each participant, specific questions from the knowledge test were examined to confirm the negative impact on teacher practices caused by a lack of teacher knowledge. In this way, the results from the knowledge test helped triangulate data from observations or interviews. The practices survey was used as a secondary data source to determine the instructional practices of each participant. However, the practices survey also acted as a qualitative instrument to help identify the practices most preferred by each participant. End of study interview questions included the reflection on classroom observations that appeared inconsistent with participants' results on the practices surveys. The view toward teaching survey was also used as a secondary data source to identify the degree to which each participant held an experimental view toward teaching. The beliefs surveys were used both to triangulate observational and interview data but also as a key component of the baseline and end of study interviews. The baseline and end of study interviews were both initiated by having participants complete the beliefs survey. Initiating these interviews through the use of the beliefs survey encouraged teachers to focus on describing their beliefs and the interaction between their belief and practices. During the end of study interview, participants were also asked to examine the results of all four of their beliefs surveys and reflect on any changes in their professed beliefs. In these ways the analyses of the interviews and observations were intricately tied to these quantitative instruments.

Baseline Interviews

For the baseline interviews, the interview protocol (Appendix E) was used to guide questioning. However, a critical purpose of the baseline interview was to allow data to emerge on its own. Subsequently the baseline interviews were conducted using an exceedingly open-ended approach. Participants guided the direction of the baseline interview and were allowed to discuss any topics which emerged during the interview. During the baseline interview, the researcher focused on asking questions to help unpack any hidden teacher beliefs. The interview protocol was used only when a participant failed to venture into a topical area of interest on their own. The Teacher Beliefs Survey was administered to begin the baseline interview in order to track changes in beliefs as well as stimulate participant thinking. One purpose of the baseline interviews was to identify the extent to which participants held and experimental view toward teaching. The interview protocol reflects themes such as motivation to change, planning lessons which challenge existing beliefs, and a focus on student thinking to evaluate lesson effectiveness. By insuring that participants discussed these issues, the participants indicated the degree to which they held an experimental view toward teaching.

The primary purpose of the baseline interview was to examine the efficacy of the *CI Model*. This was accomplished by examining the alignment between the themes which emerged from the baseline interviews and the components of the *CI Model*. In an effort to eliminate bias towards the model, all three baseline interviews were fully transcribed. The transcriptions were then divided into distinct segments centered on identifiable topics. These topical segments were then grouped under consistent themes for each participant. Finally these emergent themes were merged into a single thematic representation of the interview topics. This thematic representation was then compared to the *CI Model* to identify the extent to which the model's components incorporated the emergent themes. To help describe and explain this analysis process, a particularly robust portion of one of the interviews was used to exemplify the process below. Since the *CI Model* was designed to represent all the factors that impact teacher change, emergent themes which fell beyond model components were given particular attention.

As discussed in the literature review, some *a priori* themes were anticipated. Teacher beliefs are built on previous experiences in the classroom both as students and teachers. Background experiences which help determine teacher beliefs and attitudes were expected. It was also expected that teacher knowledge would be revealed during the interviews which helped explain certain teacher practices. It was also expected that teachers would refer to specific contextual factors that impacted their instructional practices. The views and attitudes towards mathematics of both students and parents were expected to impact instructional decision-making as were sociocultural factors, school factors, and local, regional, and national factors. For Alex in particular, it was anticipated that instructional decision-making would be impact by the end of grade test and that this factor would not be as emphasized for Stephanie and Tracy.

Example Baseline Interview Analysis

The excerpt presented below was taken from the baseline interview with Tracy and occurred from the 31st to the 41st minute of the interview. This portion of this interview was selected because this short, ten minute portion of the interview included an array of themes, demonstrated the open-ended interview technique employed for the baseline interviews, and also revealed data pertinent to both research questions. The full transcription is provided but it has been chunked into topical segments, and the process by which the segment was separated and identified is described after each portion of the excerpt. A discussion of the themes into which these topical segments were grouped and how these emergent themes compared to the components of the *CI Model* follows the excerpt and segmentation process.

Segment 1: ‘Students pulled out’.

[Researcher] So you had a lesson on money that you felt went well.

[Tracy]: Yes. They did very well in their small groups. I think they did get the lesson though. I do feel that they understood it well enough. The only concern that I have…I have two students who got pulled out during the time, math time, Monday through Thursday. It's imperative for them to be in here at that time but they can't because that's the time that they're pulled out so they did miss it, but overall, with the students that were here I felt pretty comfortable with what they acquired from the lesson.

The researcher followed up on a comment that Tracy had made earlier about that day’s lesson going well. The follow-up was supposed to spur Tracy to discuss how she evaluated lesson effectiveness, but Tracy mentioned that two students were ‘pulled out’ of math class which she indicated caused her concern about the learning of those students. Subsequently, this brief segment was identified as ‘students pulled out’. Tracy then went on to further discuss the lesson which had asked students to make $2 from the coins they were given in their small groups.

Segment 2: ’Tracy didn’t understand lesson goal’

[R] And what was the goal in the lesson? What were you hoping they would get out of it?

[T] Just the understanding of what it would take if they [to herself: I'm trying to think how to explain it] if they were given different coins to use. If they were given $2 worth of quarters and ten dimes or what they could use to make a certain amount of money...They're various ways to do that.

[R] So if I understand correctly, it's in essence a number sense, problem solving game.

[T] Yes.

This segment was identified as ‘Tracy didn’t understand lesson goal’. This segment was isolated because this particular lesson was not one that Tracy had created herself but rather a lesson she implemented directly from her curricular resources.

Segment 3:’Lesson evaluation’.

[R] How was it that you came about to determine that you felt it was successful?

[T] A lot of observation. I would go to each group and get them to explain to me exactly what they were doing…If they say "well, I used this", I love to ask "well, why?", or "tell me how you did that". I would basically do an interview with each of them when I would go to their small groups. I did not give a formal written assessment at that point for that.

[R] Would you say that's a typical technique during the lesson of seeing how it's going?

[T] For the most part. They use their notebooks-they have a math notebook they use quite often, basically every day and I like to go back through and see how they will work out a problem. We do have worksheets, but I like for them to really tell me and show me. I like the worksheets. They can draw things on there and show me how they got it and they can use pictures to give me their answers, but I really like for them to tell me and then show me with the physical in their hand.

This segment was categorized as ‘lesson evaluation’ as a key component of having an experimental view toward teaching, and even though the researcher deliberately pointed Tracy toward reflecting on how she came to the conclusion that the lesson went well, the segment typifies the open-ended interview technique utilized throughout the interviews. At this point, the researcher revisited the formal assessments that Tracy mentioned earlier as a method for evaluating lesson effectiveness.

Segments 4:’Example assessment’ and 5: ‘‘3rd grade common planning’’.

[R] You were saying that you use formal assessments?

[T] Yes.

[R] When, how, how often, what are those like?

[T] We [the 3rd grade teachers at her school] try to all plan together with our assessments. And we always do a pre-test and a post-test…They [her students] took an assessment today which took them longer than I thought it would. It's okay for the assessment to go longer. I guess I just, um, I worry until I actually look at the results.

[R] It sounds like you felt pretty good about where they were based on your classroom observations? Your individual observations and brief interviews?

[T] Yep.

[R] But you're worried…

[T] Yes.

[R] …that the assessment might indicate otherwise.

The segment above was identified as ‘example assessment’, but the segment included a short segment identified as ‘3rd grade common planning’ imbedded in Tracy’s discussion on formal assessments. These two segments were identified in this excerpt though the actual discussion flowed directly into the next segment.

Segments 6: ‘Hypothetical response to poor performance’ and 7: ‘3rd grade staying together’.

[R] Let's say you go home and grade the assessment and they didn't do very well especially compared to how you thought they were doing?

[T] Okay. [pause, deep breath] Honestly, at that point, then I'll plan my intervention activities around what I feel the majority of the class as a whole missed... If they all missed the same concept or method, then I would go back and use that in intervention.

[T] We're [the grade level teachers] all trying to stay together but it's really important for me to keep them on track and I feel like we're already going to be a day behind because of the way today went, but, um, but I don't want them to miss out on this concept because they can't move forward without them. So I'm just going to have to plan my intervention once I get the results of the assessment.

[R] Let's say that they kind of bombed the assessment across the board... Even though, let's just say, that your observations during class were that they were really doing well.

[T] Right.

[R] So let's say that there was a really stark contrast and it wasn't just in one area but across the board.

[T] Then I'm going to have to take a day. I'm going to have to take however long it takes to go back and take a look at where the breakdown was in the lesson. Because if there was a breakdown in the lesson…

[R] I am not trying to make you nervous about this assessment.

[T] No, no, no. I'm just thinking.

[R] Because I know you're probably nervous about it already.

[T] I'm hoping they did just find and it took them longer because they were really thinking about it and wanted to do well for Ms. Tracy.

Another imbedded segment was found in the segment above which again represented an *a priori* theme as a component of having an experimental view. The imbedded segment that the 3rd grade teachers tried to stay together was identified because it related to segment 5: '3rd grade common planning'. The reaction to poor student performance was a deliberate question as Tracy's response related directly to determining the degree to which she held an experimental view toward teaching.

Segment 8: 'student reaction to assessments'.

[T] I really think that they know... Assessment is serious anyway to them…It's automatic, I can see the look on their face when I say "Okay, assessment time!" And they're like "Uh, you know, okay, it's really serious. Let's do this!"

[R] And Stephanie was saying that you guys do quarterly assessments that are designed based on the end of grade tests?

[T] Yeah.

[R] And you sit them down and they take it in that testing environment.

[T] Yes.

[R] I'm sure they freak out a little bit.

[T] Totally.

[R] They haven't done it yet because you're first quarter is coming up.

[T] Right, but we had a practice EOG test at the end of the year.

This segment pertained to the anticipated impact that end of grade examinations would play in teacher planning, instruction, and reflection. This topic pertained to both research questions as the end of grade test represented a particularly important contextual factor while also playing a significant role in how teachers evaluated lesson successfulness which is an experimental view component.

Emergent themes. After transcribing the baseline interviews and identifying the topical segments as described above, segments were then grouped under common themes. In the excerpt above, eight topical segments were identified: 'students pulled out', 'Tracy didn't understand lesson goal', 'lesson evaluation', 'example assessment', '3rd grade common planning', 'hypothetical response to poor performance', '3rd grade staying together', and 'student reaction to assessments'. All three baseline interviews were transcribed and segmented topically as exemplified above. These topical segments were then grouped with other similar segments to create a set of emergent themes for each participant. For example, 'students pulled out', '3rd grade common planning', and '3rd grade staying together' were all grouped together along with several other segments (see *Table 5* in the Results Chapter) under a School Policy theme because these segments all dealt with Tracy's negotiation of policies established by the administration. Since lesson evaluation was an *a priori* theme focused on having an experimental view, segments like 'lesson evaluation' and 'hypothetical response to poor performance' were connected to themes as the segments were identified. Other segments, like ‘student reaction to assessments’ and ‘Tracy didn’t understand lesson goal’, were also related to anticipated themes but were more difficult to locate within a single theme. ‘Student reaction to assessments’, for example, related to student-teacher interaction as well as impact of EOG. In situations where a segment could have fallen into multiple themes, the most strongly associated theme was selected, though some segments fell into multiple themes. ‘Student reaction to assessments’ fell into the impact of EOG theme. Similarly, ‘Tracy didn’t understand lesson goal’ could have related to teacher knowledge, an *a priori* theme or impact of curricular resources, but it appeared that Tracy’s lack of familiarity with *3rd Grade Investigations* played more of a role here than her lack of knowledge, so this segment fell into the impact of curricular resources theme.

Overall, the eight topical segments identified in this ten minute interview excerpt fell into four themes: Impact of curricular resources, Impact of EOG, Lesson evaluation, and School policies. After the topical segments were categorized into themes, a set of themes were developed for each participant. These themes were then merged and compared to the components of the *CI Model* to help determine the efficacy of the model. The impact of EOG theme was anticipated and Lesson evaluation was a deliberately targeted theme as a component of having an experimental view. These themes were inherently connected to the *CI Model* as they were created in conjunction with the model. Impact of EOG is an obvious contextual factor which in this case represents a state policy that Tracy indicated impacted her classroom planning, instruction, and reflection. Lesson evaluation is an example of the potentially cyclical relationship between classroom instruction, reflection, and planning new lessons based on those classroom observations.

This relationship typifies the experimental method of observation, theorizing, and experimentation. However, emergent themes like impact of curricular resources and school policies acted as test items for the efficacy of the model. School policies were a more localized example of the impact of the EOG and were easily incorporated by the *CI Model* as a contextual factor. However, the impact of curricular resources was more difficult to account for using the model. This impact played a role in planning, instruction, and reflection as was the case in the segment presented while also acting as a contextual factor. The frequency and strength of the segments which pertained to impact of curricular resources ultimately led to a revised version of the model to highlight this contextual factor which, for all three participants, was a powerful contextual factor impacting the interaction between their beliefs and lesson planning, classroom instruction, reflection, and even professional development activities.

Observational Interviews

When teachers were observed teaching or planning, pre- and post-observation interviews were scheduled whenever possible. Audio recordings of these interviews were conducted whenever possible though some more informal, brief interviews were not recorded. Field notes were also taken during these interviews whenever convenient. As with the baseline interview, themes emerged spontaneously and relevant questioning occurred only when such direction was required. Also, portions of these interviews were transcribed, coded, and divided into thematic segments whenever topics emerged that fell beyond those identified during the baseline interviews. There were four purposes to these interviews. One purpose was to track changes in teacher beliefs by posing questions which helped unpack teacher beliefs as they pertained to planning, instruction, or reflection. A second purpose was to determine the extent to which the participants engaged in behaviors consistent with having an experimental view toward teaching. The third purpose of these interviews was to identify situations in which *CI Model* components helped explain the interactions between teacher beliefs, practices, and contextual factors. Lastly, the efficacy of the *CI Model* was examined throughout these interviews by searching for emergent themes that were not represented in the model.

Observations

There were two purposes to the observations and accompanying interviews. One purpose was to determine the degree to which teachers' actual practices reflected their professed beliefs and matched the practices which they reported in the practices survey and the baseline interview. Specifically, identifying practices which did, or did not, align with an experimental view toward teaching was a critical purpose of the observations and subsequent interviews. Planning sessions were observed as well since planning is indicated as playing a key role in teacher change in both the *CI Model* and by having an experimental view toward teaching. A second purpose of the observations was to triangulate data from the baseline interviews, other observations and observational interviews, and end of study interviews to help identify changes in teacher beliefs and to document changes in teacher beliefs that might be attributable to practices reflective of having an experimental view toward teaching.

During classroom observations, field notes were taken to document participants' instructional activities. Field notes of instructional activities were taken in an attempt to accurately document the various practices used by each participant. Since field notes might fail to thoroughly capture every significant event, instructional lessons were audio recorded and videotaped whenever convenient. These data were then triangulated with the data from the practices survey, the baseline interview, and previous observations and interviews with a focus on four areas of interest. Pertaining to the second research question, participants' instructional activities were examined to determine alignment with having an experimental view toward teaching and the participant's professed alignment with having an experimental view. Second, the extent to which the participants' practices aligned with data collected from the baseline interview and the practices survey was also examined. Third, observations were used to continue efforts to identify themes which might fall beyond the purview of the *CI Model*. Finally, practices which seemed inconsistent with participants' professed beliefs were targeted to help identify ways in which contextual factors impacted the interaction between beliefs and practices as represented in the *CI Model*.

End of Study Interviews

The end of study interview was used a final opportunity to address issues which emerged throughout the study and was conducted in a very different method than used throughout the rest of the study. Instead of using an open-ended format, the same interview protocol was utilized but with a strong emphasis on reflecting on the issues which emerged throughout the study. Teachers were shown the results of all four beliefs surveys and asked to examine any changes in their professed beliefs. Similarly, it was only during the end of study interviews that participants were directly asked to reflect on significant episodes that emerged during an observation or an interview. In summary, Table 2 below presents the Instruments, Data sources, and Methods of Analysis grouped by research questions.

Table 2
Research Questions, Instruments, Data Sources, and Methods of Analysis.

Research Question	Instruments	Data Sources (Primary in bold)	Method of Analysis
1) In what ways does the Contextualized Interaction Model help examine changes in the beliefs of teachers engaged in a professional development program?	• Interview protocol • Beliefs Survey • Practices Survey • Teacher Knowledge Test	• **Interview field notes** • **Interview recordings** • **Beliefs Survey results** • Observation field notes • Practices Survey results • Videos of classroom teaching • Lesson plan submissions	• Use practices Pre- and Post-test to identify changes in practice (student- vs teacher-centered). • Code baseline interviews • Identify themes for each participant. • Analyze themes across participants. • Compare emergent themes to model components. • Triangulate with results from surveys • Use post-observation interviews and on-line modules to follow-up on baseline as needed. • Code teacher confrontations with differences between interview responses, survey results, or observations. • Use observations to identify inconsistencies between beliefs and practices • Use interviews to examine impact of contextual factors on interaction between beliefs and practices
2) Does the degree to which teachers have an experimental view toward teaching account for changes in beliefs?	• Interview protocol • Beliefs Survey • Practices Survey • View toward Teaching Survey • Teacher Knowledge Test	• **Beliefs & Practices Survey results** • **Field notes from Interviews** • **Field notes from observations** • Interview recordings • Videos of classroom teaching • View toward teaching survey	• Use interview protocol to identify ways in which experimental view helped account for changes in beliefs • Use repeated measures of Beliefs Survey to identify changes (or lack of change) in beliefs over time. • Use Teacher Knowledge Test to identify areas in which participants held or lacked knowledge required to properly implement experimental view. • Use experimental view rankings to correlate with changes between pre- and post-teacher knowledge test results.

CHAPTER 5: RESULTS

The results chapter will present summaries of the baseline data, observational data, and end of study data for each participant separately. Cross-comparative analyses will also be provided when revealing or significant. These summaries will lead into a section which provides direct responses to the two research questions. The research questions will be discussed in order, and each research question will be reviewed followed by a full response to the question. The findings will be connected directly to the research question responses. Relevant findings falling beyond the purview of the research questions will also be discussed. Raw data may be presented to support responses when needed.

Findings from Pre-Test and Baseline Data

The results of the pre-test administration of the knowledge test, beliefs survey, and practices survey will be discussed. The results of the view toward teaching survey will be discussed only with reference to the baseline interviews. This discussion will include a review of the results of the baseline administration of the beliefs survey and the practices survey. The findings from each interview will be presented. The themes which emerged during each interview will be discussed. Key interview excerpts will be provided to help provide clear images of each participant as well as exemplifying the data utilized to determine emergent themes. The excerpts which pertained to specific research goals will be highlighted.

Knowledge Test and Survey Data

The results of the *Learning Mathematics for Teaching* test (Appendix A), Beliefs Survey (Appendix B), Practices Survey (Appendix C), and View toward Teaching Survey (Appendix D) appear in *Table 1* below. Alex earned the highest score of the three participants on the knowledge test, but a score of 34 is not considered significantly stronger than a score of 30. The scores of these participants can be considered quite similar and were close to the average teacher knowledge score of 34.2 from the sample of 23 teachers with a standard deviation of 8.4. The results of the beliefs & practices survey however differ in significant ways for the participants.

Table 1
Pre-Test Results of Knowledge Test, Beliefs Survey, and Practices Survey

	Knowledge Test	Average Beliefs			Practices	
Participant	Score	T	D	C	Ave TC	Ave SC
Alex	34	20	23	57	2.23	3.50
Stephanie	27	13	57	30	2.77	2.75
Tracy	31	34	33	33	3.23	2.92

The results from Alex's survey indicated that Alex tended to view mathematics as socially constructed through collaborative discourse. Stephanie tended to view mathematics as the result of individual discovery, while Tracy indicated no preference for a particular view of mathematics. The results presented above were the average percents emphasized in the three categories mathematics, mathematics teaching, and mathematics learning. Based on the literature in this area, it is useful to examine the original scores as shown in *Table 2* below. The T, D, & C represent Transmission, Discovery, and Connectionist views, respectively, toward mathematics. Alex held strong views toward mathematics teaching and learning as socially constructed, but not mathematics as a subject of study where he indicated a view that was more balanced between all three. Stephanie and Tracy expressed views toward mathematics that were consistent throughout the three categories.

Table 2
Results from Pre-Test Beliefs Survey

	Mathematics is:			Mathematics Learning is:			Mathematics Teaching is:		
Participant	T	D	C	T	D	C	T	D	C
Alex	30	30	40	20	20	60	10	20	70
Stephanie	10	60	30	20	50	30	10	60	30
Tracy	35	30	35	33.3	33.3	33.3	35	35	30

Stephanie indicated a very consistent view toward mathematics, learning mathematics, and teaching mathematics as mostly a process of individual discovery but also socially constructed. Stephanie indicated having little to no view of mathematics as the transmission from of a set of procedures from teacher to student. Tracy was even more consistent than Stephanie in her responses in all three categories, but these consistent responses indicated absolutely no emphasis among the three types of views toward mathematics, learning, and teaching. The results on the practices survey also differed among the participants. The scores presented in the table represent the average score on the teacher-centered and student-centered items. Alex indicated that he preferred teacher-centered practices ‘Sometimes’ but student-centered practices ‘Half’ to ‘Most of the Time’. Stephanie and Tracy tended to prefer teacher- and student-centered practices about ‘Half the Time’.

Alex’s Baseline Interview

Coding and themes. There were 11 distinct themes which were revealed through coding of Alex’s baseline interview data (see Table 3 below). The interview was divided into 59 topical segments and 10 of the 11 themes which emerged fit into *CI Model* components. One theme that emerged was termed Impact of Curricular Resources and was not specifically hypothesized and could be considered as a contextual factor. Table 3 presents the themes and number of topical segments that merged into that theme. The majority of the topical segments pertained to Instructional Practices and Contextual factors while the remaining interview segments were spread fairly evenly throughout the other themes.

Table 3
Themes Emerging from Alex’s Baseline Interview

Emergent Theme	Number of interview segments addressing theme (59 total)	Component of *CI Model*
Motivation to Change	4	Teacher Beliefs
Lesson Planning	5	Lesson Planning

Table 3 continued

Emergent Theme	Number of interview segments addressing theme (59 total)	Component of *CI Model*
Instructional Practices	16	Instructional Practices
Lesson Evaluation	6	Reflection
Reflection	4	Reflection
Teacher Beliefs	5	Teacher Beliefs
Contextual Factors	13	Contextual Factors
Impact of Curricular Resources	6	Contextual Factors?

Key excerpts. Alex indicated that his negative experiences with traditional teaching methods were a key motivator that drove him to search for better methods. Alex viewed his teaching role as a facilitator. Alex was asked if he had a typical or ideal lesson plan. He described his preferred lesson plan, or typical lesson script, as including student group work with a focus on collaborative problem-solving and instructional flexibility based on student engagement and understanding which he used as the key measures to evaluate lesson effectiveness. Alex claimed that his instructional planning and decision-making was influenced by curriculum, mathematical and cultural backgrounds of his students, the local and school culture, and he also referenced the national educational culture.

Alex’s experiences as a student in a traditional learning environment provided strong motivation to teach using non-traditional methods. Alex recalled that learning mathematics for him was mainly about memorizing and practicing the algorithms the teacher showed him. Later in high school, Alex started to make sense of these algorithms. When he reflected on these experiences, he noted that he wanted to teach differently than he was taught:

> What I remember about math is that when I took pre-cal, the teacher would do the problem and then do another one with the variable in a different place. I didn't understand it and had to go get help. I was so frustrated, and so ticked off, that that's all that she did. It was so boring. There is no way that, as a teacher, you're sitting up there feeling good about doing this. They [education professors] had to teach you a better way to do this.

Alex was also driven by a desire to help his students feel better about learning mathematics than he had felt. His experiences in high school convinced him that he wasn’t a ‘math person’, and he chose to avoid taking higher level mathematics courses. In retrospect, Alex felt that his teachers, and the way he was taught, convinced him that he wasn’t a math person. These experiences have in turn driven Alex to teach mathematics differently: “I don't want to be that teacher that makes someone think they're not a math person.” These experiences motivated Alex to learn how to teach mathematics using better methods: “So that's what I also think about. Is there not a better way to do this?”

Alex’s preferred lesson plan or typical lesson script was reflected in his planning. He wanted to insure that students were invested and interested in the mathematics that they were studying and tried to utilize relevant problems found in or created from the math program resources. His ideal script would begin with an interesting problem that was relevant to his students and aimed at his teaching goal for that lesson. He would hopefully then be able to follow the students' lead from the problem posed and adjust his teaching based on their thinking and engagement. Alex indicated a preference for kids to work in groups, and ideally, for groups to come up with different methods for solving the problem and then explain their approach to the rest of the class. "I'm going to show different methods hoping kids will find one that works". Moving off script based on where students directed the lesson was part of Alex's lesson script. It's "okay for lessons to have loose ends" which sometimes occurred with tougher problems, and "it's okay to just stop a lesson if it's not working".

Alex indicated a view toward mathematics as an interconnected, rather than linear structure. "Math is doing things different ways and finding your own method". He described himself as a facilitator and focused on student thinking, engagement, and interactions with other students. Alex felt he was "good at recognizing when a kid is having trouble and facilitating change for that child". Regarding student engagement with the problems posed or examples used, "we use money a lot because it's so important to these kids". Alex felt that he needed to move kids from "concrete to abstract" but that "abstraction doesn't mean you're smarter". Alex also adjusted his practices based on the mathematical backgrounds of his students.

Generally, Alex indicated that he used student engagement and interest along with formal assessment results to determine the effectiveness of his instruction. Alex also stated that he would use unit post-tests to assess the effectiveness of his instruction after the lesson along with assessing lessons through student engagement, thinking, and interaction during the lesson. When students failed to “get it on the assessment”, Alex claimed that he would alter his instruction and “make it more concrete” for them. However, Alex felt that his ability to reflect and alter his instruction based on assessment results was impacted by the curricular resource. Teachers at Alex’s school used a spiraling curriculum in mathematics which Alex indicated affected his ability to impact student growth.

Overall, Alex referred to multiple factors which impacted his instructional practices. These factors included dynamics within the classroom, the school climate and professional expectations, local and national contextual factors and systems but also his own personal background experiences as a student and as a teacher. Alex also clearly believed that the curricular resources selected by the school impacted his teaching in significant ways. Transcriptions of other salient topical segments can be found in the discussion section of the conclusion.

Stephanie’s Baseline Interview

Coding and themes. As shown in *Table 4* below, Stephanie’s interview was divided into 44 total topical segments. 40 of the segments were coded under the hypothesized themes with the remaining 4 segments being coded as the Impact of Curriculum. 3 interview segments were coded as both Instructional Practices and Contextual factors themes. A large number of interview segments were coded as Contextual factors, while only one interview segment was coded as Teacher Beliefs. The remaining segments were spread relatively evenly throughout the other hypothesized themes.

Table 4
Stephanie's Baseline Interview Themes

Theme	Number of interview segments addressing theme (44 total)	Component of *CI Model*
Motivation to Change	5	Teacher Beliefs
Lesson Planning	4	Planning
Instructional Practices	9*	Instructional Practices
Lesson Evaluation	6	Reflection
Reflection	3	Reflection
Teacher Beliefs	1	Teacher Beliefs
Contextual factors	15*	Contextual factors
Impact of Curricular Resources	4	Contextual factors

*3 interview segments were coded as both instructional practices and contextual factors.

Key excerpts. Stephanie's experiences in primary and secondary school, her college education program, and as a pre-service and in-service teacher all combined to provide strong motivation for Stephanie to seek out different instructional methods. Stephanie found reform-oriented instructional strategies more effective than traditional due to her focus on student thinking and the use of data to evaluate lesson effectiveness. The school climate and structure emphasized this use of data as well as collaborative planning and reflection and community engagement. The discussion section includes the particularly salient interview transcriptions which led to these conclusions.

Tracy's Baseline Interview

Coding and themes. As shown in *Table 5* below, Tracy's baseline interview was coded into 42 total segments. These 42 segments of the interview fell into 6 different theme categories. 41 of the interview segments were coded under the hypothesized themes with the remaining segment being coded under Impact of Curriculum. One interview segment was coded as both Instructional Practices and Contextual factors. The vast majority of the interview segments were spread fairly evenly among Motivation to Change, Lesson Evaluation, and Teacher Beliefs. Six segments fell under contextual factors and just one fell under Lesson Planning. No segments were coded as Instructional Practices or Reflection.

Table 5
Tracy's Baseline Interview Themes

Theme	Number of interview segments addressing theme (42 total)	Component of *CI Model*
Motivation to Change	11	Teacher Beliefs
Lesson Planning	1	Lesson Planning
Lesson Evaluation	10	Reflection
Teacher Beliefs	14*	Teacher Beliefs
Contextual factors	6*	Contextual Factors

Table 5 continued

Theme	Number of interview segments addressing theme (42 total)	Component of *CI Model*
Impact of Curricular Resources	1	Contextual Factors?

*1 interview segment was coded as both Teacher Beliefs and Contextual factors.

As was the case with Alex and Stephanie, Tracy's interview data included references to the impact of the curriculum. Unlike Alex and Stephanie, none of the segments from Tracy's interview were categorized as Instructional Practices or Reflection. However, several of the interview segments which were categorized as Lesson Evaluation and Teacher Beliefs pertained to Instructional Practices and Reflection as well. Significant portions of the interview involved instruction and reflection. Another key reason that the data from Tracy's interview appears to focus on instruction and reflection less than the data from Alex and Stephanie is because, while Alex spent significant time describing his typical script and Stephanie related her current instructional practices to her previous experiences, Tracy focused her conversation on her beliefs and relied on her team and the math program to dictate instruction. Tracy tended to couch her instructional statements in terms of how her beliefs impacted her decision-making.

Key excerpts. Tracy had been teaching fourth grade at the participating school for two years before the study began and was moved to third grade during the study year. Prior to working at the participating school, Tracy had taught in a charter school. As mentioned previously, Tracy and Stephanie were on the third grade team together at their school. This team included two other teachers, but Stephanie was the only returning member of the team. The principal at the participating school had decided to transition the school into a Professional Learning Community two years prior to the study. This transition resulted in some turnover at the school, and Tracy was initially hired and then switched from third grade to fourth grade as a result of this turnover.

Tracy had a clear understanding of her motivation to change which was readily apparent during the interview. The excerpt below began during the third minute of the interview while discussing Tracy's reasons for participating in the professional development program. This portion of the interview also illustrated the role played by the math program, the impact of the team framework at the school, the relationship between Tracy's previous experiences and current situation, and some of Tracy's beliefs towards mathematics and teaching. The excerpts which support these conclusions can be found in the discussion section. As was the case with both Alex and Stephanie, Tracy's experiences as a student strongly impacted her motivation to grow professionally.

The Contextualized Interaction Model

In *Table 6* below, the interview segments from all three participants were aggregated. Every segment from the interviews was categorized under themes from the *CI Model* except for the 11 segments that were categorized under Impact of Curricular Resources. The *CI Model* accounted for at least 92% of the interview segments, and all other interview segments fell into only one additional theme. The majority of the interview segments pertained to the Teacher Beliefs component of the model with Contextual factors, Reflection, and Instructional Practices claiming a similar portion of the segments. A significantly smaller portion of the interview segments fell into the Lesson Planning component of the model and the Impact of Curricular Resources theme. There was significant variation in the number of interview segments which fell into each model component among the participants.

Table 6
Baseline Interview Themes and CI Model Components

		Number of Interview Segments				
Model Component	Theme(s)	Alex	Stephanie	Tracy	Aggregate	Percent of total
Lesson Planning	Lesson Planning	5	4	1	10	7%
Instructional Practices	Instructional Practices	16	9	0	25	17%
Reflection	Lesson Evaluation, Reflection	10	9	10	29	20%
Teacher Beliefs	Beliefs, Motivation to Change	9	6	25	40	28%
Contextual Factors	Contextual Factors	13	15	6	34	23%
	Impact of Curricular Resources	6	4	1	11	8%
	Total:	59	44	42	145	103%

*103% because 4 segments were placed into 2 separate themes.

The interview questions and protocol were designed using the various components of the *CI Model*, so it was expected that many of the participants' responses would fall into these categories. However, the participants were permitted to direct the interview toward any topics of their choosing as was illustrated by the excerpts provided above. The excerpts provided also illustrate the tendency for portions of the interviews to range across several various components of the model without the researcher's direction. The variation in the areas of emphasis in the different interviews reveals the open-ended manner in which the interviews were conducted. Also, the large number of interview segments provides further evidence of response freedom. Finally, only one theme emerged that was not a component of the proposed *CI Model*, and this theme emerged in all three interviews. The *CI Model* provided a valuable framework for the examination of the interview data from these participants, and could be strengthened by containing a curriculum component.

Experimental View toward Teaching

It was hypothesized that for beliefs and practices to change, teachers would need to 1) Be motivated, through a desire to grow professionally, to implement divergent instructional practices, 2) Implement instructional practices that challenged beliefs, and 3) Focus on students' mathematical thinking as the key measure of lesson effectiveness. With little coaxing, all three participants revealed critical information about their motivation to grow professionally and their willingness to implement divergent practices. Since these interviews did not include classroom observations, the data regarding instructional implementation and lesson evaluation was expected to be limited. However, all three participants also revealed important information regarding instructional implementation and lesson evaluation.

1) Motivation. All three participants indicated a strong commitment to teaching mathematics differently than they had been taught. All three participants described their experiences as students in a very traditional learning environment. These participants described learning experiences which aligned with a transmission view toward mathematics, teaching, and learning. All three also described not enjoying the traditional learning environment and indicated that they felt this transmission approach toward teaching mathematics was not successful.

All three teachers discussed administrative support with significant differences becoming apparent. Stephanie and Tracy's school had engaged in converting to become a PLC when Stephanie did her student teaching there four years prior to the study year. As members of a PLC, Stephanie and Tracy and been involved in selecting the *Investigations* program for the school. The teachers chose to pilot the program during the previous spring after which they chose, as a school, to adopt the program K-4. The administration at their school appeared to be implementing the PLC ideals properly which ask teachers to deliberately test teaching practices by measuring practice effectiveness in terms of student outcomes. It would appear that this administrative influence was providing additional motivation and direction for Stephanie and Tracy to engage in testing practice effectiveness. Both Stephanie and Tracy were hired by the principal at their school to assist this transition into a PLC. Stephanie had been teaching third grade at her school for several years and was recognized as the team leader, while

Tracy had only two years of experience teaching fourth grade at their school, and was teaching third grade for the first time in her career.

The support which Alex perceived however seemed to be directed differently. In discussions with Alex's principal prior to the Baseline Interview, it was obvious that Alex knew his principal felt he was a strong teacher. But during the Baseline Interview, Alex made it clear that he felt that support was contingent on his performance as judged by student scores on the state's end of grade test.

[A]: I hate that but my butt's on the line because it [the state's end of fourth grade test] says 'Travis Allen scores and if they're 1, 1, 2, 2, …" [The principal]'s going to have me in the office saying 'what are you doing?'

[R]: You feel like your butts on the line?

[A]: Absolutely, even though they say that's it's not, if I don't produce-it's a business, school's turned into a business model-you've got to show production.

Despite extensive efforts to create similar sociocultural environments, these three teachers appeared to be motivated in vastly different ways by their school climate.

2) Instructional implementation. It was originally expected that observations of lesson planning and classroom instruction would be required to determine the degree to which the participants implemented instructional practices that challenged their beliefs. However, all three participants provided pertinent information during their Baseline Interviews. Of significant surprise to the researcher, all three participants indicated that they obtained their lesson plans and pacing from their curricular resources as opposed to designing their lessons and using their resources discretionally. The program being implemented in Stephanie and Tracy's school was a scripted program with a strong reform-based orientation which they started to pilot during the previous spring. On the other hand, Alex was using an unscripted, strongly traditional program with which he was fairly familiar even though this was his first year teaching fourth grade. Alex's typical lesson script included going off script and letting student interest, engagement, and comfort level direct the lesson which might have indicated openness toward implementing divergent practices. However, Stephanie and Tracy both indicated a motivation to implement the *Investigations* program as intended which would mean implementing reform-oriented practices.

As mentioned previously, the participants completed a Practices Survey prior to participation in any professional development activities. Alex had indicated a tendency to engage in student-centered practices while Stephanie and Tracy indicated no preference toward teacher-centered or student-centered practices. Alex and Stephanie described taking a facilitating or mediating role when teaching which indicated a commitment to student-centered practices, while Tracy did not indicate a particular view. Since *Investigations* was a reform-oriented program, if Stephanie and Tracy implemented the scripted lessons as intended, then those lessons should have challenged any traditional beliefs Stephanie and Tracy held. Stephanie was very clear regarding her beliefs about the program when asked about her response to some teachers' allegations that *Investigations* was too scripted:

[Stephanie]: My response to that is you don't need to be in teaching. This [*Investigations*] is not set-up for you to teach them how to do something. It's set-up for them to figure it out on their own in their own way and to share what they've learned with the other students.

On the other hand, Tracy indicated that she was trying to become more comfortable with the divergent practices being asked of her when using *Investigations*:

[Tracy]: I don't know. I don't know. I'm not afraid to let them experiment with their ideas as opposed to last year when we began the program in January, I was not comfortable with them expressing their views as much or. I was afraid to go off the beaten path. I was afraid to do that.

Despite being the oldest of the three participants and having the greatest number of years of teaching experience, it was evident that Tracy was moving through the process of determining what she believed. For example, there were 18 different instances in which Tracy stated "I don't know" when discussing her own ideas and beliefs.

The data provided during the Baseline Interviews was consistent with the Practices Survey data, but, as expected, these data failed to provide any conclusive information regarding the teachers' views toward implementing instructional practices which challenged their beliefs. However, since all three participants had experienced a traditional mathematics program taught from a transmission view toward teaching, the baseline data did reveal areas of focus for future classroom observations.

3) Lesson evaluation. Alex appeared to focus on student engagement and formal assessments to evaluate lesson effectiveness.

[R]: You've got a lesson plan, something you're hoping to do. You're going to have to evaluate as you're getting into the lesson, how it's going. How do you do that?

[A]: You throw up some leading question. When you put the problem up there, "what I do…" They're in tables working together. 1 or 2 minutes working alone and then discuss with your table. As they're discussing I'm walking around and seeing how many people are actually discussing. If they don't have something to discuss, if they don't understand it, they're going to be discussing anything and everything else. Or if they're not saying anything then you know. So you gauge if they're in the realm of the target. As you're walking you can ask a basic question like "Why? How do you know that" you can see if they're reasoning is way off or not. It's just a good teaching practice.

[R]: How do you know when a lesson has flopped?

[A]: I'm a big believer in student interest and motivation. If they're not motivated and they're not into it, they don't understand what I'm talking about, so they've shut me out. Also, if they're not into the lesson then they're not learning. You have to have interaction, just like the PD, if I'm going to give up on a problem, you know a 10 year old will. Also, assessments…we assess every ten days which is a quick turn around. If they don't get it on the assessment, I know I have to go back and re-teach it.

Alex also indicated that he relied on student thinking and understanding to guide his instructional decision-making. Alex’s lesson script included following his students’ lead based on their understanding. Subsequently, student thinking appeared to be an inherent component of Alex’s method of evaluation. Alex indicated that he used inquiry and observation during class to evaluate lesson effectiveness as revealed through his description of his typical teaching script:

[A]: After the problem (to start off the lesson), I'm usually on the fly and making up something to extend the problem based on how they're doing. It just depends on their understanding, if I have to do more unpacking.

[R]: So you're looking for how they're engaged, how they're understanding it?

[A]: These kids are pretty open, so pretty much, if kids are engaged, then you're doing something right.

[R]: Okay, you think they're doing well during class but then they bomb the assessment. What do you do?

[A]: That happens a lot and you have to go back and get those manipulatives and make it more concrete, show them other ways, etc.

And though neither Stephanie nor Tracy, perhaps due to the scripted nature of their brand new math program, indicated that they adjusted their lesson plan during the lesson based on student thinking, Stephanie did indicate that she relied heavily on student thinking as a key indicator of lesson effectiveness.

Stephanie appeared to emphasize student thinking and discourse as the primary measures of lesson effectiveness both of which appeared to be assessed strictly through observation during class. When describing her typical lesson script, Stephanie indicated that her students were doing well:

[S]: They have no problems. They can explain their thinking. They can explain why they used those numbers and why they put them in the order that they put them in. They can explain it just as good as I can.

And then toward the end of the interview when asked specifically about how she can tell when a lesson “is working the way it’s supposed to”:

[S]: If they can apply the skill in a problem solving setting and if they can talk about what they're doing. If they can't do that, then we know it's not working and we need to back up.

And when she reflected on the Beliefs Survey and what she emphasized regarding mathematics teaching and the prompt: ‘Understanding being made explicit’:

[S]: I think is important because they need to be able to tell you 'I understand this because', 'I know that this is what I'm doing and why'.

In addition to focusing on her observations of student thinking and discourse during class, Stephanie also indicated that she used students’ work on homework to assess her lessons:

[S]: We don't have a whole lot of time in the classroom to do paper pencil work. Our homework is reflective of what we taught in the class that day. So they do homework 3 times a week based on the skills they're working on. I know that if they are getting homework to work on their own and they’re struggling with it, then I know that they need to go over that again.

While reflecting on the Beliefs Survey, Stephanie indicated that she used student assessments to assess her own teaching.

[S]: I feel like the assessments are two-fold: to find out what the student knows and to find out how I've taught it correctly.

Since Stephanie and Tracy were working on a team together which met daily to co-plan, it was not surprising that both of them made similar comments when asked about how they gauge lesson effectiveness.

Tracy had taught a lesson just prior to the baseline interview which she felt went rather poorly because the lesson did not progress as she had planned. The timing of this lesson led to questioning which revolved around discussing specific lesson examples. Tracy indicated that she evaluated lessons effectiveness through a focus on observation of student thinking, though she revealed that she sometimes lacked a clear understanding of the lesson objectives and also judged lesson effectiveness based on how well the lesson followed the lesson plan for that day. A portion of this transcription was utilized to exemplify the transcription analysis process. Please see that portion of Methodology Chapter for that supporting data.

[R]: How have some of [the new lessons you've taught] gone? We can take a look at the one you did today if you want.

[T]: Uh, sure…today was not a great day.

[R]: What was the lesson today?

[T]: First we did assessments... they're actually working with creating a thousands chart booklet so that did not go over well at all today so I'm having them go back tomorrow because by the time we finished up the assessment, we were lacking in time for them to understand why they needed that and what it was going to help them with.

[R]: So what's the goal of this lesson?

[T]: Well, really, gosh, I'll be honest with you, I have no idea. I mean I have no idea. I know that sounds strange. I was so focused on getting that assessment completed today and just making the booklet.

[R]: Why are you saying today didn't go well?

[T]: Just because it was slow getting started because they took longer with their assessment. They had a four page assessment that they needed to complete. It took them longer at finishing that than I thought…It just did not go well...I had students taking much, much longer than what I anticipated so it worries me a little bit about that final end of unit assessment. I'm not sure why it took them so long.

Tracy also discussed a lesson that went well and emphasized a focus on student thinking, but she once again revealed a lack of understanding of the lesson's objectives.

Tracy also described a formalized process of collaborative reflection on assessment data to inform practice which represented another component of efforts to enact the practices of a PLC. However, the students had not yet taken one of these assessments. Finally, Tracy indicated that she liked to take some time to reflect on how her lesson went during the day.

[R]: You said that after a lesson, you take some time to decide if the lesson went well.

[T]: Yes.

[R]: When does that usually occur?

[T]: Usually after the students…Well, I can't say that. [pause] There are some days that if the students are working on …

[R]: …cuz you obviously check on it during the lesson.

[T]: Yes. There are some days, if the students begin working on an activity and I've completed the lesson, I'll start thinking, reflecting about what happened, what were the responses, and if I question it, sometimes at that point I'll just say "okay guys, let's stop for just a moment and let's go back" and we'll go back…And there are days that I do it after they leave. If I'm looking over work or looking through their math notebooks. I don't know. Sometimes I have to write notes down for myself and then the next morning when they come back in I'll say "guys, lets go back to this for just a few minutes."

Overall, all three participants acknowledged a desire to focus on student thinking during a lesson to evaluate the effectiveness of that lessons. Tracy's apparent lack of understanding or awareness of lesson objectives indicated that she would struggle to accurately judge the effectiveness of a lesson since she would not be looking for appropriate indicators of student thinking. Alex's description of a teaching script that varied based on student thinking and engagement along with inquiry revealed a strong dependence on student thinking. Similarly, Stephanie described evaluating her lessons using student thinking with a strong emphasis on discourse. All three participants also mentioned the use of assessments to inform planning. Of note, none of the participants indicated that lesson effectiveness was measured in terms of discipline, and none of them appeared to consider placing blame on the students, classroom climate, resources, etc. Rather, each participant revealed a degree of comfort with revisiting objectives when students appeared to have difficulty with assessments.

Experimental views of participants. The baseline data were collected to provide a preliminary indication of the extent to which participants held an experimental view toward teaching. It was hypothesized that holding an experimental view would help explain changes in the beliefs of the participants. Though planning and classroom observations were needed to further triangulate the data presented thus far, a fairly clear baseline image has formed. The participants' beliefs will be discussed in the next section, but first a summary of the findings regarding the extent to which the participants appeared to hold experimental views toward teaching will be provided. A significant and unexpected commonality among the participants is that all three indicated a strong motivation to teach in ways that were markedly different from their experiences within a traditional teaching environment. Though a goal of the professional development program and perhaps not unexpected since the participants were selected by their principals to join the PD program, this common motivation among the participants could lead to a lack of differentiating data despite efforts to obtain participants who appeared to hold different beliefs. One important difference in the sociocultural climates for the participants is the potential impact of the EOG for Alex and the PLC for Stephanie and Tracy. All three participants revealed the potential role played by these contextual factors, and these factors also represent a key difference between them.

Regarding the planning and implementation of lessons which challenged teachers' beliefs, all three participants utilized lessons provided by their math programs. For this reason, the planning component of having an experimental view toward teaching appeared to be moot for Stephanie and Tracy. However, Alex's open lesson script and a commitment to a reform-based pedagogy despite using an exceedingly traditional style math program should have led to interesting planning and implementation. It was also important that Alex and Stephanie appeared to have clear teaching images as facilitators while Tracy appeared to be struggling for a clear teaching image despite having more teaching experience. However, it was clear from the survey and interview data provided that observational data were also required to obtain accurate pictures of how the participants actually planned and implemented their lessons. Finally, all three of the participants appeared to place a strong emphasis on student thinking and assessments as measures of lesson effectiveness. Again, the need for observational data was apparent, but the participants certainly indicated views which aligned with this component of having an experimental view. Alex and Stephanie in particular appeared to focus on student thinking while also having clear lesson goals in mind. Since Alex indicated that he utilized the spiraling nature of the mathematics program used at his school, this component of Alex's evaluation of lesson effectiveness was deemed an important focus during planning observations. Similarly, the formative assessments which Stephanie and Tracy indicated they would use to alter instruction would be given attention once that data was collected.

Overall, it appeared that Alex's practices would most closely align with having an experimental view with Stephanie indicating strong alignment as well. An important factor was that Alex indicated that his script included adjusting his lessons based on student thinking. However, Stephanie and Tracy were using a reform oriented math program which could have significant implications since all three teachers planned on implementing lessons obtained from their respective resources. Another important aspect which would require examination was the role played by EOG for Alex and the PLC model at Stephanie and Tracy's school. These contextual factors, based on the *CI Model*, could have played a significant role in the participants' decision-making. Though some beliefs have been clearly revealed through this investigation into the degree to which the participants' have an experimental view toward teaching, a more specific and thorough discussion of the data regarding teacher beliefs will be discussed below.

Teacher Beliefs

Before any formal professional development work had been conducted with the participants, they completed a teacher beliefs survey. These data were discussed earlier in the Findings. During the Baseline interviews, the participants were asked to retake the Beliefs Survey with the intent of using their responses to prompt further discussion and investigation. The data from the first and second measures with this instrument can be found in *Table 7* below. It's important to note here that a misadministration occurred when Alex was allowed to see his previous Beliefs Survey results instead of being asked to retake the survey so that the results could be compared. Alex stated that he agreed with his original scores, but there is no way to know how he would have in fact filled out the survey. Alex's data need to be viewed with this misadministration in mind.

Table 7
Results from Pre-Test and Baseline Beliefs Surveys

		Mathematics is:			Mathematics Learning is:			Mathematics Teaching is:		
Participant	Survey	T	D	C	T	D	C	T	D	C
Alex	1	30	30	40	20	20	60	10	20	70
	2*	30	30	40	20	20	60	10	20	70
Stephanie	1	10	60	30	20	50	30	10	60	30
	2	5	45	50	5	50	45	10	60	30
Tracy	1	35	30	35	33.3	33.3	33.3	35	35	30
	2	25	25	50	0	50	50	20	50	30

*Misadministration: Alex did not retake Beliefs Survey but indicated that he still agreed with his original responses.

In addition to indicating that he still agreed with his original responses, Alex briefly discussed his belief that teaching and learning mathematics involved students connecting previously learned material.

[A]: They are all connected and that's the major thing that I try to teach now is 'Guys, you did this last year and that was a stepping stone for this year'… It is a stepping stone and you do have to teach it that way. Try to show them the whole puzzle instead of a piece here and a piece here. I don't know if that's the right way. Education is such a revolving door anyway that, who's to say 20 years from now my kids are in school and in high school that they're not back to the way we learned it.

It is significant that Alex used these statements to justify his connectionist view toward teaching and learning mathematics but chose not to change his view toward mathematics as a subject to reflect this connectionist perspective even though these comments related strongly to that view.

This re-examination of the Beliefs Survey also prompted Alex to reveal an important attitude toward students' conceptions of mathematics:

[A]: Even if they're doing it the wrong way, they're doing SOME type of math. You just got to figure out what type of math they're doing and how to direct them or guide them in a certain way. I guess that's what I see myself doing more of. I'm definitely not as open as I probably should be.

This comment then led Alex to describe himself as a facilitator, though he also mentioned that he was trying to become a better facilitator. These two excerpts clearly depict Alex's belief that he viewed mathematics in a strongly non-transmissionist fashion. Alex's second comment presented as a strong discovery view toward mathematics. But again, Alex also stated that the fairly balanced views towards mathematics as a subject presented in his original beliefs survey were still accurate. These data seemed to indicate that Alex held conflicting views towards mathematics as a subject.

Stephanie’s beliefs survey responses appeared to be notably similar to her original responses and presented a slight shift in her views indicating an even greater, though evenly balanced, emphasis on the discovery and connectionist views toward mathematics, mathematics learning, and mathematics teaching. She also seemed to have moved even further away from the transmissionist view placing virtually no emphasis on that perspective. Unlike Alex, Stephanie placed consistent emphasis on each perspective across the different views toward the subject, teaching, and learning. Consistent with comments Stephanie made during the Baseline Interview, the survey data appeared to indicate that Stephanie held a very clear image of herself as a teacher which she stated was as a moderator or mediator. Examining her responses to the survey prompted Stephanie to make some significant comments. Regarding mathematics as a subject…

[S]: I like to allow the kids to create their own concepts and own methods. Do what you need to do to find the answer. What works best for you because no one is the same...This gives them the opportunity to think in their own way.

Stephanie clearly rejected the transmissionist view but revealed her mutual appreciation for the discoveriest and connectionist views.

[S]: They only hear a small percentage of what I say. So if they're discussing and sharing their ideas and we're working together, first of all you have a partnering role so they see you as a partner not as authoritator. And they will listen to each other and themselves more than they will listen to me… In math, very little has a rule that can't be changed. There's no one way to do anything…I would say that in some instances, yeah, it needs to be done this way, I can't think of any off the top of my head…No universal truths [laughs].

When reading the “Mathematics learning is…” prompt, Stephanie indicated her continued rejection of the transmissionist, authoritarian approach toward teaching.

[S]: (Reading from survey) ‘Individual activity based on watching, listening, and imitating…’ They watch very little of what I'm doing. They listen to almost nothing I say, and only imitate things that they shouldn't be imitating.

However, Stephanie did acknowledge that students will tend to imitate the way she does things.

[S]: They will. If I've shown them how to do a number line, some of them will try to use a number line because that's the way they learn. They imitate what somebody else is doing as long as they can understand what they're doing. So if I say the number line is my favorite way to solve this problem, most of them will use a number line. And with regard to “Mathematics teaching is …” and “Understanding being made explicit”…

[S]: I think it’s important because they need to be able to tell you 'I understand this because', 'I know that this is what I'm doing and why'. I also need to give them explicit 'this is why you're doing this', 'you're going to need to know this because...' … So letting them know why they need to do it helps them build an understanding of what they're doing.

As seemed to be the case throughout the baseline interview and was reiterated when she completed the beliefs survey, Stephanie appeared to have a very clear image of herself as a mathematics teacher who consistently placed equally strong emphasis on discoveriest and connectionist views toward mathematics and rejected the transmissionist view. In addition to having very clear beliefs toward mathematics, Stephanie also appeared to hold these beliefs with great conviction. Alex also appeared to hold his beliefs strongly, but the misadministration of the survey made it difficult to accurately measure his level of conviction. Tracy, on the other hand, was quite obviously searching to obtain greater conviction.

As planned, the beliefs survey provided a nice prompt for Alex and Stephanie which led to the majority of their combined 15 interview segments coded as Teacher Beliefs. However Tracy had 25 interview segments which were coded under Teacher Beliefs and the majority of those segments were prompted by the survey. Tracy's survey also presented significant change when compared to Stephanie. While Stephanie altered her percentages by an average of just less than 8%, Tracy adjusted her responses by an average of 14%. Again, it is regrettable that Alex's survey was administered incorrectly. Also, Tracy spent more time (15 minutes) discussing the survey during the baseline interview than Alex (5 minutes) and Tracy (10 minutes). These data support the overall impression that Tracy's beliefs system was the least well defined of the three. Subsequently, one might expect that Tracy's beliefs might change more significantly than the other participants while also presenting decreased variability towards the end of the study.

These baseline data provided clear evidence of multiple ways in which the *CI Model* appeared to be helpful in examining teacher beliefs. Though perhaps unnecessary, it was certainly expected that observational data would add to these indications that the model was both accurate and encompassing. Though these baseline data helped create strong images of the participants, it was equally clear that observational data were going to be required to reveal the instructional practices which the participants actually implemented in the classroom. It was also apparent that observations and continued interviews would be required to illuminate the relationships between the beliefs and practices of the participants. These observations and interviews would also be required to determine the degree to which the participants held an experimental view and the extent of the impact of that factor on teacher change.

Observational Findings

Summary of Observations of Alex

Data from multiple sources indicated that Alex's beliefs and practices were strongly aligned with having an experimental view toward teaching. And prior to Observations #4 & #5, Alex's practices appeared to coincide strongly with his beliefs. Alex had indicated a strong motivation to teach in ways that were better than his traditional experiences as a student. When Alex's focus on student conceptions and his typical lesson script was considered in concert with his students' comfort level with the use of inquiry and problem-posing, it became clear that Alex utilized instructional methods which deviated significantly from his experience with traditional methods. Alex's beliefs and practices appeared to align strongly with having an experimental view toward teaching. However, some inconsistencies had been noted.

Alex made some statements during the co-planning session and Observations #4 and #5 which indicated a gap in his own understanding of this concept. For example, even though Alex told his students to make sure they thought of 30x20 as thirty and twenty, he failed to correct a student who answered Alex question "How do we multiply 30x20? Why do we just do 3x2?" with "because anything times 0 is 0." Also, at one point Alex stated "it doesn't really matter" where the ones go when multiplying 34x20 using the lattice method which made 34x20 equal to 30x24. In fact, he had to ask the students' forgiveness for "making a real bonehead mistake." On the Content Knowledge Test, questions A12 required teachers to recognize a model for showing partial products. Alex marked this question *e) I'm not sure* on the Pre-test administration. Of note, he did get this question correct on the post-test version. Of even greater significance, Alex indicated that the lesson objective focused on students' use of the commutative and associative properties to simplify multiplication when in fact Alex focused on using the distributive property. The evidence indicates that Alex lacked the knowledge required to enact his instructional beliefs as intended.

During the planning session, Alex indicated a potential reluctance to test out lessons with which he lacked comfort. The willingness to try out new lessons is an important component of viewing lessons as experiments. It is also important to recognize that the textbook which Alex was using did not show multiple approaches for solving problems but rather emphasized following one specific and usually very traditional procedure repeatedly. This issue came to the fore when Alex asked his students to explain why you "add a zero" when multiply tens digits. The textbook specifically referenced 'sliding over' and multiplying 3x2 instead of 'thirty times two' which was the phrase Alex used during class. In this instance Alex was asking his students to understand a method in a way that was not supported by the curricular resource. Adding to this problem was the fact that several students employed the traditional algorithm for multi-digit multiplication because their parents had shown them the method. Lastly, Alex engaged in an instructional behavior which appeared inconsistent with his beliefs. Alex's tended to assume a position at the front of the classroom despite his commitment to letting the class take the lead, letting students present their approaches, encouraging group work and discourse, and his view of himself as a facilitator. However Alex had also indicated that there was too much material to cover before the end of grade test and that he perceived a need to insure a consistent pace. This perception would certainly account for Alex directing and even driving the class's progress as illustrated by the following excerpt from the baseline interview:

> The sad thing is, from April on, you don't teach hardly any new material because you are reviewing so that part of the book may not get taught. You're going to have to teach it but not in a facilitating fashion. You're teaching it as a multiple choice problem. I hate that but my butt's on the line because it says [Alex]'s scores and if they're 1, 1, 2, 2, … [Alex's principal]'s going to have me in the office saying 'what are you doing?'

Alex's beliefs and practices appeared consistent and aligned well with having an experimental view toward teaching in addition. However, these instructional practices which had seemed so consistent with his professed beliefs throughout various data sources and over time appeared to suddenly change during Observations #4 and #5. But the *CI Model* provided a framework for accounting for what appeared to be inconsistencies between Alex's beliefs and practices. His instructional practices deviated from his beliefs, at least in part, because of the following factors: a) teacher knowledge, b) the limitations of the curricular resources, c) the instruction provided at home, and d) the pressure of the end of grade test. These factors were identified because teacher knowledge was recognized as part of Teacher Beliefs while the curricular resources, home instruction, and end of grade test were recognized as Contextual factors. However, it is equally important to note that even though Alex's knowledge and these contextual factors impacted his instructional practices, it would appear that Alex learned from these lessons because he adopted practices and beliefs which aligned with having an experimental view. To begin, Alex's motivation to teach differently than he was taught motivated him to plan a lesson in which he taught various methods for multiplying multi-digit numbers instead of using the traditional algorithm shown in the book and presented by some students' parents. If he had only used the approach shown in his book which was the same as that shown to some students by their parents, then the students' lack of understanding of that method might not have ever become evident. Also, Alex's focus on student thinking further revealed the difficulties his students were having which might not have become evident if he had not asked his students to explain their reasoning. Since Alex was willing to adjust his teaching based on student thinking, he extended this lesson instead of sticking to a predetermined schedule despite the pressure of covering the material for the end of grade test. It should also be noted that, whether it's due to the formal professional development over the summer and throughout the school year, the work Alex and the researcher did together, or Alex's own work with his students, Alex did not miss question A12 on the Teacher Content Knowledge Post-test. There were several similarities and some important differences between these findings with Alex and those with Stephanie.

Summary of Stephanie's Observations

These observations were intended to help reveal the extent to which having an experimental view toward teaching explained changes in teachers' beliefs. However, it is difficult to determine the extent to which Stephanie revealed having an experimental view toward teaching. The baseline interview provided multiple indicators supporting

Stephanie's experimental view. However, despite efforts on the part of the researcher to observe full teaching cycles, there were few opportunities to observe and interview Stephanie as she planned a lesson, implemented that lesson, and then reflected on that lesson. There was only one opportunity to do so with Alex but no full lesson cycles with Stephanie were observed. Even though Stephanie appeared strongly motivated to improve and alter the instructional methods to which she had been exposed as a student, implemented reform-oriented methodologies, and seemed to focus on student understanding as the measure of lesson effectiveness, there was not enough data to indicate the degree to which Stephanie adopted an experimental view. There was also data which conflicted with the experimental view such as her implementation of a lesson which she acknowledged failed to address student understanding and had apparently not led to strong student performance on last year's end of grade test. But the data regarding changes in Stephanie's beliefs and practices revealed through the use of the *CI Model* may have compensated for the lack of evidence regarding an experimental view toward teaching.

The final classroom observation and planning session presented an impression of Stephanie which aligned with the baseline interview data as well as the first and third observations. Based on these data sources, Stephanie appeared to practice a reform-oriented pedagogy with a strong focus on inquiry, problem-solving, and collaborative group work. Her students' comfort level with these methodologies provided the strongest evidence of alignment between Stephanie's professed beliefs and practices. However, the other half of the observations were indicative of practices which deviated in significant ways from Stephanie's professed beliefs and lesson script. During the second observation, Stephanie's lesson implementation was impacted by Stephanie's lack of understanding of the lesson goal, lack of experience with the lesson, the nature of the materials provided to students, and her students' prior exposure to the traditional algorithm. Stephanie's planning for the fourth lesson observed was significantly altered due to a meeting she had to attend. This lesson would probably be best described as a complete flop and source of agitation for Stephanie, the assistant teacher, and the students. However, it is difficult to know the degree to which Stephanie's implementation of this lesson was negatively impacted by her departure from class. The fifth lesson observed followed Stephanie's lesson script but revealed methods which she felt were successful in the past despite being the antithesis of her professed beliefs. Stephanie even acknowledged as much. These methods and the structure of grouping the classes appeared to depend strictly on the end of grade test and the content knowledge of these teachers. And the final observation and planning session presented methods which directly aligned with Stephanie's professed reform orientation. This lesson revealed a teacher who fluidly utilized inquiry in the classroom as well as students who were well versed in group work, discourse, problem solving, and inquiry.

These conflicting impressions exemplified both alignment with and inconsistencies between this teacher's beliefs and practices. Fortunately, the *CI Model* which framed this investigation helped identify the various reasons why Stephanie's beliefs and practices appeared inconsistent at times. The factors which appeared to explain the inconsistencies between Stephanie's professed beliefs and her practices were a) the students' background knowledge, b) Stephanie's background knowledge & experience, c) the end of grade test, d) reflection on student data, e) the school structure and climate, f) the curricular resources, and g) formal professional development. These data appear to reiterate some of the findings from the data provided by Alex as well. The third participant in the study provided data which, when combined with the data from Stephanie and Alex, provided overwhelming evidence supporting the various ways in which the *CI Model* was useful in examining teachers' beliefs and practices.

Summary of Tracy's Observations

It appeared, initially, that Tracy's practices were not consistent with her professed beliefs. However, the *CI Model* helped reveal the various factors which impacted Tracy's practices. Contextual factors like her prior teaching experiences, the recession, and the end of grade test interacted with Tracy's beliefs and knowledge to drive her focus away from student thinking and toward simply keeping her job. Tracy's practices did not align with her professed beliefs because she felt forced to conform to contextual factors. The baseline data described Tracy as a teacher who possessed a strong motivation to test new practices. Tracy indicated that she was committed to teaching her students in ways that differed from her experiences, but the results of the Beliefs Survey (Appendix B) indicated that she was uncertain about her views toward mathematics, teaching mathematics, and learning mathematics. Interview data confirmed this lack of certainty. Tracy stated that she valued student thinking but recognized that she lacked some of the knowledge, skills, habits, and experience needed to assess it. The assessment tools provided also failed to properly reveal student thinking. Tracy also struggled with maintaining classroom behavior. But the key issue affecting Tracy was the need to keep her students caught up with the rest of the third graders.

Tracy had indicated that she measured lesson successfulness in terms of the lesson "going as planned". The choice had been made at Tracy's school to ability group, and Tracy had one of the two groups of lower performing students. The third grade teachers were supposed to maintain the same pacing among all four groups as well. In an effort to maintain discipline, maintain the pace of the class, and to make sure the lessons went "as planned", Tracy chose to not let students explain their thinking during class. This practice appeared to be influenced by Tracy's lack of knowledge and experience and her lack of facility using inquiry to reveal student thinking. Tracy showed an increasing tendency to maintain a position in front of the class. She also chose to model the algorithmic methods with which she was the most comfortable instead of following the *Investigations* script. Whether Tracy held a strong or weak experimental view toward teaching, her choice to measure lesson effectiveness in terms of lessons going as planned combined with the school's structure and several other powerful contextual factors to focus Tracy's efforts on keeping pace with her colleagues and maintaining classroom discipline. This situation digressed to such an extent that, by the end of the year, Tracy seemed consumed with the goal of doing whatever the other teachers were doing even though she believed they should do things differently to meet the needs of their students. In many ways, Tracy's experience represents the perfect maelstrom of conflict between the various factors and components represented in the *CI Model* and the impact those factors can have on a teacher's practice.

End-of-Study Findings

The end-of-study data will begin with a comparison of the pre- and post-knowledge test and practices survey results of the participants. A discussion of the beliefs surveys will follow the presentation of the knowledge test and practices survey data. For each participant the beliefs survey was administered multiple times in an effort to track changes in the beliefs of the participants over the course of the year. Trends in these data sets between and amongst all three participants will be discussed. Following these quantitative data, the end-of-study interview data will be discussed for each participant. The findings section will conclude with a general summary of the findings.

Knowledge Test

The pre-test versions of the Knowledge Test (Appendix A), Beliefs Survey (Appendix B), and Practices Survey (Appendix C) were administered early in the summer prior to any PD. The post-tests were administered late in the school year after all of the in-school year PD sessions. The same instruments were used for both the pre- and the post- test. As discussed in the methodology, Alex, Stephanie, and Tracy were invited to participate in this study because the scores on the pre-Knowledge Test were similar, 34, 27, and 31 respectively, while their scores on the Beliefs Survey (Appendix B) presented interesting differences. The pre- and post-Knowledge Test scores are displayed in *Table 8* below.

Table 8
Pre- and Post-Knowledge Test Scores

Participant	Pre-Test Score	Post-Test Score	Change (Post-Pre) Score
Alex	34	46	+12
Stephanie	27	32	+5
Tracy	31	21	-10

A description of the Teacher Knowledge Test (Appendix A) was provided in the Methods Chapter. Recall that these participants were a subset of a larger grant project and were chosen deliberately selected because they had similar scores on the knowledge pre-test. The three teachers participating in this study took the same pre- and post-test at the same time as the other teachers participating in the grant study. The increase in Alex's scores of +12 was greater than any other study candidates even though his pre-test score was right at the 34.2 average. Stephanie's scores also showed a greater than average increase. However, Tracy was one of only four teachers whose post-test scores were lower than their pre-test scores, and her scores showed a greater decrease than any other participant as well as her post-test score ranking the lowest of the 20 participants who took both tests.

These significant differences despite efforts at obtaining participants with similar knowledge pointed toward some type of cause. Perhaps most importantly, Tracy and Stephanie had very similar scores on the pre-test. They taught at the same school in the same grade across the hall from each other. They used the same math program and planned together throughout the year. However, the post-test scores for Stephanie and Tracy were radically different. It is also important to note that, as a group, the teachers taking the post-Knowledge Test expressed discontent about taking the assessment at the specific time when it was administered. Several teachers specifically referenced the stress they were under because students were taking the EOG.

Practices Survey

The pre- and post-Practices Survey scores for each participant are displayed in *Table 9* below. The Practices Survey (Appendix C) was designed to determine the extent to which teachers reported student-centered versus teacher-centered practices. The maximum score for any question was a five which indicated that teachers felt they used those teaching methods almost all of the time while a score of one indicated almost never using a practice. A score of three indicated using practices half the time. Recall that Alex, Stephanie, and Tracy were asked to participate in this study in part because of apparent differences in their beliefs and practices. Alex had indicated one of the strongest tendencies to utilize student-centered practices among the teachers who took the test. Stephanie had indicated no preference for either type of practice, while Tracy had indicated a slight preference for teacher-centered practices. The pre- and post-Practices Survey results appear in *Table 9* below.

Table 9
Pre- and Post-Practices Survey Data

	Pre-Test		Post-Test			
	Practices		Practices		Change (Post-Pre)	
Participant	Ave TC	Ave SC	Ave TC	Ave SC	Ave TC	Ave SC
Alex	2.2	3.5	3.3	3.4	+1.1	-.1
Stephanie	2.8	2.8	2.7	2.9	-.1	+.1
Tracy	3.2	2.9	2.9	3.2	-.3	+.3

TC=Teacher-Centered Practices. SC=Student-Centered Practices

The changes in Stephanie’s surveys were representative of the teachers sampled, while Tracy demonstrated a more significant change from a preference for teacher-centered practices to a preference for student-centered. Alex however indicated very little change in his use of student-centered practices (3.5 to 3.4) but a fairly large increase in his use of teacher-centered practices (2.2 to 3.3). In fact, Alex was one of just eight teachers who indicated an increase in his reported use of teacher-centered practices, and he indicated a significantly greater increase than the other seven. Alex also reported a slight decrease in his use of student-centered practices which was not surprising since his pre-test average of 3.5 was actually the highest score of any of the 22 teachers. Only three teachers had higher scores than Alex’s 3.4 on the post-test. But the increase in Alex’s reported use of teacher-centered practices is significant since most teachers reported tending to alter their practices toward more student-centered behaviors.

The sixth observation of Alex was conducted right around the same time that these post-test data were collected. During that observation, Alex followed the same teaching script that he had described during the baseline interview and had exhibited throughout the observations. However, Alex had also indicated:

> The sad thing is, from April on, you don't teach hardly any new material because you are reviewing so that part of the book may not get taught. You're going to have to teach it but not in a facilitating fashion. You're teaching it as a multiple choice problem. I hate that but my butt's on the line because it says [Alex]’s scores and if they're 1, 1, 2, 2, … [Alex’s principal]'s going to have me in the office saying 'what are you doing?'

Alex may have been implementing more teacher-centered practices due to his efforts to review for the end-of-grade test. The increase in Tracy's reported use of student-centered practices and the decrease in her reported use of teacher-centered practices might be attributable to Tracy's efforts to implement *Investigations* properly. Throughout the observations and interviews, Tracy had indicated her uncertainty about her beliefs toward mathematics and mathematics teaching. However, Tracy seemed to obtain greater conviction regarding the use of reform-based teaching strategies like those supported by *Investigations*. Proper implementation of these strategies requires the use of more student-centered practices which could account for the changes in Tracy's survey responses.

Beliefs Surveys

Each participant completed the beliefs survey four times, though the results for Alex's second run were compromised as the researcher mistakenly allowed Alex to view his Pre-Test responses (see *Table 1* in the Methodology section). The participants completed the beliefs survey for the first time prior to the provision of any PD. These data are listed as the pre-test survey. The second administration of the beliefs survey occurred early at the beginning of the school year as a component of the baseline data after the summer PD had been provided but prior to any observations. The third administration occurred in conjunction with the Post-Test administration of the Knowledge Test late in the school year after all of the observations and the vast majority of that school year's formal PD sessions. The researcher met again with the participants during the second round of summer PD sessions which is when the fourth and final beliefs survey was administered. The results of the Beliefs Surveys will be discussed in conjunction with the end-of-study interviews as the examination of beliefs was the focus of those interviews.

Alex's End-of-Study Interview

The end-of-study interviews occurred in early August, close to a full year since the baseline interviews, and the participants were very relaxed and upbeat even though they had just engaged in a tough week and day of PD. Each interview began with the fourth and final administration of the Beliefs Survey (Appendix B), but the discussions between the researcher and the participants were very easy and informal.

Once Alex completed the Beliefs Survey (see *Table 10* below), the researcher asked him about the similarities in his responses to 'Math is …' and 'Learning math is..' and the differences between these two views and his views toward 'Teaching math is…'.

Table 10
Alex's Beliefs Survey Results Compiled

	Mathematics is:			Mathematics Learning is:			Mathematics Teaching is:			Averages		
Administration	T	D	C	T	D	C	T	D	C	T	D	C
Pre-Test	30	30	40	20	20	60	10	20	70	20	23	57
Baseline*	30	30	40	20	20	60	10	20	70	20	23	57
Post-Test	33	33	34	33	33	34	20	60	20	29	42	29
End of Study	10	40	50	10	40	50	20	40	40	13	40	47
Averages:	26	33	41	21	28	51	15	35	50	21	32	47

T= Transmission view, D=Discovery view, and C= Connection view.
*Misadministration: Alex only confirmed his Pre-Test responses.

Alex indicated that these views were similar because he felt that “a student will learn math by doing what the 'learning is' says”. However, he also felt that he needed to use more teacher-directed instruction with younger students because “their ability to learn it more deeply grows with their understanding” which he felt depended on their age. He also stated that “[younger] students aren't inquisitive enough for the ideal inquiry-based approach.” However, Alex qualified this view by noting the impact of students’ prior experiences:

[A]: But you've got to realize that they're coming from a more teacher directed background.

[R]: Does the way students have been taught impact the way you teach?

[A]: Absolutely, you have to meet them where they're at. That’s teaching style.

[R]: Can you elaborate on that?

Alex went on to explain that he felt he had to slowly transition his students toward the ideal use of inquiry over the course of the year so that he’s “teaching just the way I want to by the end of the year.” He reiterated that he was able to move much quicker with the study group because he had taught them before: “I was able to take that facilitator role faster this year because I had them last year.”

When Alex was asked about other factors that impacted his teaching, he mentioned issues pertaining to students’ understanding of concepts, social maturity level, societal backgrounds, time, and discipline. However, Alex made specific mention of the support he received from his principal. Prior to the year of the study, Alex had taught for three years at a different school. Alex transferred from that school because he felt as if he were unable to do what he thought was best for kids due to pressure from the principal.

Alex indicated that his principal really pushed for growth and improvement while his previous principal did not.

Stephanie's End-of-Study Interview

Once Stephanie had finished the Beliefs Survey, the researcher explained that the goal for the interview was to try and explain any changes in her beliefs. However, Stephanie's beliefs, as presented in *Table 11* below, did not appear to change in any consistent fashion. Stephanie and the researcher together examined the results of her Beliefs Surveys and came to the conclusion that the results on the Pre-Test and End of Study administration were similar because they represented her overall beliefs. While the results on the baseline and post-test administration reflected changes in her beliefs and practices that were reactions to the types of students Stephanie was teaching.

Table 11
Stephanie's Beliefs Survey Results Compiled

	Mathematics is:			Mathematics Learning is:			Mathematics Teaching is:			Overall		
Administration	T	D	C	T	D	C	T	D	C	T	D	C
Pre-Test	10	60	30	20	50	30	10	60	30	13	57	30
Baseline	5	45	50	5	50	45	10	60	30	7	52	42
Post-Test	5	80	15	5	15	80	5	80	15	5	58	37
End of Study	10	60	30	10	45	45	10	70	20	10	58	32
Averages:	8	61	31	10	40	50	9	68	24	9	56	35

T= Transmission view, D=Discovery view, and C= Connection view.

Stephanie listed a litany of factors which impacted her teaching that year which she felt were reflected in her Beliefs Survey responses. The researcher noted the consistencies in her responses with the post-test administration in the spring representing the only significant inconsistency. The researcher noted that, on the Post-test administration, Stephanie's emphasis on the Connectionist view switched to the Discoveriest view on the 'Mathematics is…' section, but the reverse occurred for the 'Learning is…' view. Stephanie attempted to determine why she might have been viewing things differently during that time frame and focused on external factors that would have impacted her responses.

[S]: I don't know. This group of kids was just weird. And I had the kids who were…a lot of them were on the top edge of the grade level and just a bit over, so they had to be challenged for this one right here (points to 3. on Learning is…), which would probably change a little bit if I had a more…because I really only had about three students in my class who couldn't function with the challenge.

[R]: Okay, now, that would make total sense. These two, the first and second time that we looked at your beliefs, that was basically really before you got to know your students at all.

[S]: And the first semester, even though we had our students grouped according to their ability, they were having us still teach the same exact thing to all of the students. So we really struggled with that, because we spent eight weeks on addition and subtraction, and my students didn't need addition and subtraction at all….So they complained a lot.

[R]: Because of that?

[S]: Yeah, they did not play the games. They didn't care.

[R]: So would you say that your beliefs, when you took this survey in the spring, might have been specifically with reference to your group of students this year.

[S]: Probably. Hmm, hmm.

[R]: Where as these (the pre-test and baseline administrations) were consistent with these guys (the end of study administration) because they kind of deal with your beliefs overall.

[S]: Right. Hmm, hmm. I agree.

[R]: Is that accurate?

[S]: Yep. Yes, sir.

The conclusion was that the spring, post-test administration of the Beliefs Survey was inconsistent with the other surveys because it was more reflective of her practices which were impacted by her students and the school's structure. Stephanie went on to mention some other factors which she felt impacted her instruction.

[S]: That's (pointing to the Transmission view for Learning is) how I was taught. Watching, listening, and just imitating the steps.

[R]: Alright, that number one there?

[S]: Number 1. Yeah. I always struggled with math and wasn't very good at it.

[R]: And do you feel that this view towards learning math is the same as what's being expressed here (1. on Teaching is...)?

[S]: Yes.

[R]: Okay. So that view (Transmission perspective on Teaching is…) towards teaching…that's how you were taught?

[S]: Yes.

[R]: And you were taught as if you would learn that way (pointing toward Transmission view toward Learning is …)

[S]: Um, hm.

[R]: And yet clearly you don't try to do much of that?

[S]: The students do. Yeah.

[R]: Why is that?

[S]: Because they've seen that. Their parents were taught that way and so when they go home and do homework, their parents teach them that way. And so they get conflicting information.

This excerpt was indicative of the ways in which Stephanie's end of study interview reflected much of the data found throughout the year's observations and interviews. Over the course of the interview, Stephanie also reiterated that her instruction was impacted by student behavior, the time allotted for teaching mathematics, and the impact of the *Investigations* curriculum. The researcher also asked Stephanie to reflect on her instruction of the measurement unit.

Recall that in March, Stephanie was observed teaching a lesson on measurement during which she appeared to focus on teaching her students a cute pneumonic for converting between common units. This lesson seemed drastically different than the other lessons observed and in distinct contrast to her professed beliefs. During the end of study interview, Stephanie was asked about that lesson's effectiveness. She revealed that the pre- and post-test data had indicated little growth in the area of measurement. She readily acknowledged that those lessons for that unit had not been effective. She also revealed several different factors that she felt impacted her teaching of that unit. The end of study interview offered an opportunity to investigate Stephanie's opinions on the factors which impacted her instruction. She referenced a lack of planning time and lack of resources. She claimed that she would have preferred to work on that lesson, but they simply lacked the time to do so. Stephanie also noted the impact both of restrictions placed on the amount of time they can work on math as well as the lack of time allotted to cover this unit before the end of grade test. Stephanie indicated that the lack of understanding of her coworkers also impacted instruction as they chose to combine classes so that the entire third grade could be taught by just two teachers. It should be noted that Stephanie indicated that several of these decisions were made by the administration and beyond her control. This excerpt is included in the discussion portion of the conclusion since it helped shed so much light on what appeared to be a distinct set of inconsistencies between Stephanie's beliefs and practices.

Tracy's End-of-Study Interview

The first time that Tracy completed the Beliefs Survey, she indicated virtually no preference for any view toward teaching mathematics. This apparent lack of certainty or conviction was supported during her baseline interview as well, but her responses on the Beliefs Survey at that time showed stronger, albeit still mixed, views toward mathematics, learning, and teaching mathematics. Her strongest views toward mathematics appeared on the post-test administration of the survey, but her views toward learning and teaching mathematics continued to waiver. On the End of Study administration however, Tracy's responses for *Mathematics is…*reverted back to those on the pre-test administration while she seemed to reiterate a preference for the Discovery and Connection views over the Transmission view towards learning and teaching. The results of the Beliefs Surveys for Tracy appear in *Table 12* below.

Table 12
Tracy's Beliefs Survey Results Compiled

	Mathematics is:			Mathematics Learning is:			Mathematics Teaching is:			Overall		
Administration	T	D	C	T	D	C	T	D	C	T	D	C
Pre-Test	35	30	35	33	33	33	35	35	30	34	33	33
Baseline	25	25	50	0	50	50	20	50	30	15	42	43
Post-Test	10	10	80	20	30	50	33	33	34	21	24	55
End of Study	33	33	33	10	45	45	25	50	25	23	43	34
Averages:	26	25	50	16	40	45	28	42	30	23	35	41

T= Transmission view, D=Discovery view, and C= Connection view.

Tracy's end of study interview began with a review of the results of her beliefs surveys.

[R]: Why do you think you emphasized this one [80% Connection on Mathematics is …] so much back in the spring?

[T]: Well, I think…everything I base, lately, base my decisions on has to do with *Investigations* and how we share our ideas and how students work together in a group. It's creative. It's the creative process, the thinking process for them. And I think about that a lot and I hold it as very important.

[T]: (re-reading the connection view toward math): And there is so much discussion in our group. I mean it's so verbal in the beginning, then it's so hands on, you know. It's really interesting.

When asked to explain the balanced percentages on the end of study administration in light of the clear preference for the Connectionist view toward mathematics during the post-test administration, Tracy provided a much clearer impression of her views towards mathematics than that represented through the beliefs surveys.

[R]: So, why did you balance these two (Post-Test Teaching and Learning is ...) here when you were so clearly unbalanced before? You know, when you did that in the spring?

[T]: The operation of my classroom this year was more teamwork among students, collaborative discussion, hands on workshops. And it's not even just in math actually. We did that in reading through groups. And I think that we did explore, you know, our learning and investigations and really in centers and reading as well. So I think of all subjects as an exploration I guess…I think that's one reason why I went with these higher percentages. I definitely disagree… I don't think that students can learn by listening. I don't think they're learning that way. I think they're memorizing at that point and they're not really experiencing what they need to know. You know, that's the way I learned though in school. We had to do what the teacher did. We listened.

[R]: But I thought you couldn't learn that way?

[T]: I can't. I mean. I struggled. So it's really difficult.

[R]: So would you say that's how you learned or that's how you were taught?

[T]: That's how I was taught.

[R]: So apparently in the spring, you believed strongly that learning was more of an interpersonal activity which it sounds like what you've been describing. And yet now…

[T]: Which is so strange now because I think back… I personally have done so much reflecting as a teacher in the last couple of months of school because of the meeting that I had with [the principal] in March and it's just really, you know. I see the importance of how it changed me as a teacher. You know, reflection has definitely changed me as a teacher for the better and I think that for students to reflect upon their work as well. I think that's just another key ingredient to learning, to their education.

[R]: So it sounds like you're saying you're not really sure why you emphasized [the connectionist view for mathematics on the post-test] and didn't really place any emphasis on [the end of study version].

[T]: Well, I don't think that…I'll be honest with you I knew that reflection…I know that reflection or reflecting on your experiences as a teacher is really important. And I know that students are supposed to do that, but I don't think I ever really incorporated that into my career and into my classroom as much as I thought...I...I don't think I did it as much as I needed to.

[R]: But you filled this questionnaire out after you would have had that meeting with [your principal]. This is just a couple months ago?

[T]: Yeah. In April.

[R]: So you're just not sure?

[T]: I'm not really sure. I don't think I was there yet…I was still grasping what I was doing as far as the additional lesson plans and how that was flowing.

The excerpts above were taken from five minutes of the end of study interview. These excerpts clearly revealed the complexities involved in attempts to measure beliefs. Tracy conveyed views toward mathematics and mathematics teaching and learning which clearly opposed those expressed on the beliefs survey she had completed minutes earlier. For example, Tracy had indicated 33% agreement with a Transmission view toward mathematics, 10% agreement with a transmission view toward learning mathematics, and 25% agreement with a Transmission view toward teaching mathematics. However, during the interview she indicated that students simply cannot learn from a transmission view. The views she expressed during the interview aligned far better with the results of the beliefs survey she completed months earlier. Instead, her responses on the end of study survey most closely resembled her pre-test responses which she completed before engaging in any professional development. Later, without any prompts, Tracy would comment:

I think [the professional development provided by the grant] was an awesome experience, participating in that. Honestly, this year, I've had more professional development than I've had altogether. I feel like I've gotten more out of the [two grants] than I did out of grad school.

The week before the end of study interview, the three participants, to gain experience as educational leaders, had led professional development activities for the second cohort. But despite her own statement regarding the impact of the PD and her experiences throughout the past year, Tracy’s responses on the end of study beliefs survey indicated little change compared to the pre-test. The responses on the beliefs surveys appeared to be both inconsistent and at odds with Tracy’s very clear and unprompted expressions of her own beliefs.

Recall that Tracy’s final observation had revealed that she had met with her principal who was concerned about Tracy’s teaching. The researcher followed up on this issue during this interview. Tracy explained that her principal had met with her after on observation had very clearly indicated the need for Tracy to plan better. Tracy was asked to submit her lesson plans to her principal a week beforehand, and she was told to make those plans very detailed. During this portion of the interview, Tracy explained why she had moved toward valuing reflection, written reflection in particular for her. She revealed that she had started evaluating lesson effectiveness by focusing on reflection. This approach was in stark contrast to those she had indicated during the baseline interview which had focused on lessons “going as planned”. But most poignantly, Tracy revealed the stress caused by the experience. Tracy went on to comment that overall, she felt the school year was successful because of all she learned. It was at this point that Tracy commented about learning more from this year and the PD that was offered than she had from graduate school. The expectations placed upon Tracy by her principal obviously led to increased stress for Tracy, but she indicated several positive outcomes as well. One of these outcomes was an improved understanding of how to utilize reflection to improve instruction. The following excerpt revealed the importance which Tracy indicated she had started to place on reflection. This focus on reflection was a key to developing professionally was a result of efforts to meet her principal’s expectations.

[T]: I think when I met with [the principal], because we met every couple of weeks, and I think when I met with her to review my lesson plans and my binder, she mentioned, I had space on the side, and she said "this would be a good space for you to write your reflections" and I was like "OH!"

And later…

[R]: So you think writing down your reflective ideas was really important for you?

[T]: Yeah, because for me to just to speak it, it's just that way, but if I write it down, I have to re-read it when I go back into those lesson plans, and you know, it helped me the next week in planning and…

[R]: So you think reflecting is important?

[T]: Yes.

[R]: How come?

[T]: We grow through reflection. We understand ourselves better. I believe. I feel like it helped me get a better grasp, a direction. I guess a more targeted goal, direction in my career as a teacher and in my lessons for the students. It didn't help just one aspect of me. It helped a lot of parts…(pausing) Just thinking. Yeah, it's not just professional. It was personal. The benefit of actually writing it down and having that where I can read it. To remind myself of this and what I was thinking. I mean it really did. It gave me a more driven purpose I think.

Tracy clearly indicated that she had started placing a much stronger emphasis on the importance of reflection, but she also indicated that she was unsure of the type of information that would best support her reflection. Tracy had indicated that she valued reflection, and she had also clearly articulated various ways to measure lesson effectiveness. It was surprising that Tracy was unable to articulate that the information regarding lesson effectiveness would be the ideal data upon which to reflect.

Summary of End of Study Findings

The end of study interviews presented as much data as the baseline interviews. Discussing every issue which these interviews brought to the fore is beyond the scope of this portion of the results, but the discussion portion of the Conclusion includes several of the more salient excerpts from each participant. However, there were several issues common amongst the participants that were noteworthy. For all three participants the results of the *Mathematics is…* portion of the end of study beliefs survey aligned most closely with the pre-test results. Conversely the only trend found with the other two sections of the survey was that the responses varied widely and almost wildly at times. The average standard deviation in the participants' responses for each view were 12.4* for Alex and 11 for Stephanie and Tracy. Alex's average of 12.4 only included the three administrations. Each participant also expressed view during the interview which appeared to be at odds with their survey responses. Alex indicated the need to utilize teacher directed instructional techniques due to his students' background experiences both at home and in previous classroom even though he indicated little agreement with a transmission orientation. Stephanie revealed that time constraints led to a significant impact on her instructional practices despite her consistent preference for the non-transmission views. And most strikingly, Tracy had no explanation for why the beliefs she expressed during the interview were at complete odds with those indicated on the survey and yet in distinct alignment with those indicated on the post-test survey. The beliefs surveys appeared to show little consistency over time for each individual participant as well as with the beliefs professed by each participant. Between the participants, little consistency was found as well with the single exception that each participant indicated a consistent preference for non-transmission views. Tracy's statements regarding the impossibility of students learning within a transmission environment were significant in light of this seeming consistency. It is noteworthy that all three participants tended to decrease the amount they weighted the transmissionist view toward mathematics, learning, and teaching over the course of the study. However, this trend is weak at best and certainly not mathematically significant due to the very large standard deviations.

The consistent impact on instruction of contextual factors stood in stark contrast to the lack of consistency found within and between the beliefs survey results. The curriculum was mentioned as a factor impacting instruction for all three participants. All three mentioned the effect of time constraints for planning and/or teaching, and all three also noted the impact of the formal professional development they received throughout the year. School policies, ability grouping in particular, impacted the planning and/or the instructional practices of all three teachers as well. Alex and Stephanie mentioned the impact of student behavior, and student behavior was a theme underlying the intervention taken with Tracy. The impact of the administration was an important factor for Tracy and Alex, though they were impacted in strikingly different ways.

The remainder of the Results Chapter will be committed to connecting the findings presented above directly to the research questions. In addition to connecting these findings to the research questions, a response to each research question will be provided.

Research Question #1

The first research question focused on the use of the *CI Model* as a tool to help examine changes in teacher beliefs.

Research Question #1: In what ways does the Contextualized Interaction Model help examine changes in the beliefs of teachers engaged in a professional development program?

One goal of the study was to demonstrate that the *CI Model*, which evolved from and incorporated existing models of teacher change, was a useful tool for examining changes in teacher beliefs and practices. A unique component of the *CI Model* is that the model strove to represent all the various factors that can impact teacher change. It was hoped that the study would demonstrate the integrity of the model. This first research question includes this study goal. However, this research question goes beyond demonstrating the integrity of the model. Since the *CI Model* was created by merging previous models, there was little doubt, as was the case in multiple preceding studies, that data would be found to support the model. Rather, the goal of *Research Question #1* was to identify the ways in which the model assisted this study's examination of changes in teacher beliefs. There were two important responses to *Research Question #1*: a) As discussed below, the *CI Model* proved to be an essential tool in this study's examination of changes in teachers' beliefs by framing data collection and analysis and b) The *CI Model*, in its original form, failed to properly model the interaction between teachers' beliefs and the curriculum.

The *CI Model* profoundly impacted the data collection process and subsequently the quality and nature of the data collected. In 2007, Philipp proposed that

> …as a research stance in studying teachers and their beliefs, we researchers assume that contradictions do not exist. Taking this stance when we observe apparent contradictions, we would assume the inconsistencies exist only in our

> minds, not within the teachers, and would strive to understand the teachers' perspectives to resolve the inconsistencies…researchers who assume that inconsistencies do not exist will attempt to better understand teachers' beliefs systems and that the circumstances surrounding the teachers' practices will often …lead to resolution of the inconsistencies (p. 276).

This process occurred in this study due to the use of the *CI Model*. Inconsistencies appeared to exist for all three participants, but in every case, contextual factors helped account for the perceived contradiction. Alex described a student centered view toward instruction in which he took the role of facilitator. But as the end of grade test drew near, Alex deliberately adopted a more teacher-centered, direct instruction methodology for the express purpose of preparing his students for the test. Stephanie's similar emphasis on facilitating and her fluent use of inquiry were both completely abandoned when she tried to teach measurement. However, she recognized and acknowledged that she would have preferred to teach the unit differently. She referenced the lack time provided for covering that unit, the school's structure of ability grouping while maintaining pacing throughout the grade level, as well as a lack of curricular resources as reasons why she failed to teach that unit the way she would have preferred. A lack of teacher knowledge throughout the grade level drove the choice to merge the classes which greatly altered the learning environment. And the most profound example for Tracy came with the fear of financial security. Worried about losing her job, she chose to plan without her team in an effort to deliver her lesson plans to her principal a week in advance. Tracy then focused not on her students' understanding of the material to guide her decision-making during the lesson but was driven to stay in line with her lesson plans. These three examples typify the ways in which the contextual factors modeled in the *CI Model* of teacher change impacted the interactions between teacher beliefs and teacher practices. Moreover, these examples also demonstrate the way in which the *CI Model* was utilized as a framework for data collection by focusing areas of observation and structuring interview questioning.

The *CI Model* not only framed the data collection process but the analysis of that data as well. As shown in *Table 6* in the Results Chapter, almost every theme identified from coding of the baseline interviews was accounted for in the *CI Model*. The single exception was the impact of curricular resources which will be addressed in the next section. This section will focus on identifying and describing the ways in which the model helped to examine changes in the beliefs of these participants. With the exception of the impact of curricular resources, every baseline interview segment fell into the *CI Model* components. Moreover, the themes which emerged over the balance of the study continued to fall into the model components. The *CI Model* components consistently represent the themes which emerged over the course of the study, with the exception of curricular resources. The *CI Model* structure itself acted as a framework for the analysis. The analysis provided below will follow the *CI Model*'s structure by beginning with an analysis of two common teacher beliefs themes. The analysis will move along with the model to then summarize the contextual factors which appeared to mitigate the interaction between teacher beliefs and teacher practice. The analysis will continue moving from the teacher outward by first discussing classroom-based factors, followed by school-based, community, state, national, and ending with worldwide factors. And since teacher beliefs provide the focus for the *CI Model*, the analysis will begin there.

Teacher Beliefs

For this study, teacher knowledge was considered to be a subset of teacher beliefs. In the *CI Model*, teacher knowledge was represented within the model component of teacher beliefs. As described by Philipp (2007), teacher knowledge was considered a specific type of belief held with less emotional connection and subsequently more subject to change. As expected teacher knowledge was a recurring issue for all three participants. At times, the knowledge of these teachers provided strong foundation for their practice, but for each participant, a lack of teacher knowledge hindered their practice. For example, all three participants demonstrated a reliance on traditional algorithms. Even as each indicated a desire to support students' use of multiple approaches and in spite of PD which directly addressed alternate algorithms, all three participants showed their students only the traditional algorithms for addition and multiplication. Only in Alex's class and only through the direct intervention of the researcher was any alternate procedure demonstrated. And when this alternate procedure was demonstrated, Alex questioned his students' understanding of the traditional algorithm. Another common issue regarding teacher beliefs was quite unexpected.

A surprising similarity among all three teachers was the motivation to teach in ways that differed from their traditional experiences. All three participants held the underlying belief that math should be taught differently than the way in which it was taught to them. Moreover, each participant also believed they were capable of doing so. Alex's comment below probably provides the best summary of this critical and motivating belief:

> What I remember about math is that when I took pre-cal, the teacher would do the problem and then do another one with the variable in a different place. I didn't

> understand it and had to go get help. I was so frustrated, and so ticked off, that that's all that she did. It was so boring. There is no way that, as a teacher, you're sitting up there feeling good about doing this. They had to teach you a better way to do this.

This underlying motivational belief, to teach differently than they were taught, was a theme that re-merged for all three throughout the study.

Teacher knowledge and a belief in the inferiority of traditional methods were examples of the teacher beliefs component of the *CI Model* which is central to the model. The model depicts the contextual factors which mitigate the interaction between teacher beliefs and other components like teacher practices. The focus for this study was the examination of the interaction between teacher beliefs and teacher practices and the impact of the contextual factors represented by the *CI Model*. For this reason, classroom observations played a central role in data collection along with interviews and the beliefs surveys. The mitigating effects of contextual factors on teacher practices, as well as some other model components, were observed throughout the study. A vast array of contextual factors was noted and this array is discussed below.

C*ontextual Factors*

The summary of the contextual factors will follow the structure of the *CI Model* by extending outward from the classroom. Contextual factors at multiple levels were found that mitigated the interaction between the beliefs and practices of all three participants. Contextual factors were found at the individual level, classroom level, school level, as well as the beyond school level. Specific examples for each participant at each level will be provided.

At the individual level, each participant was impacted by the alignment between their curricular resources and views toward teaching and learning mathematics. For Alex, his curriculum's focus on practicing singular, traditional algorithms contrasted directly with his focus on teaching students multiple approaches. For Stephanie, the *Investigations* curriculum was particularly supportive of her views toward teaching, but when she had to teach measurement and lacked supportive resources, her instruction regressed to that with which she was taught. For Tracy however, the *Investigations* program provided her with the support she needed to help clarify her views toward mathematics. For each participant, the curricular resources were an important factor mitigating the interaction between their beliefs and practices. And this mitigation occurred on a personal level.

Within the classroom, each participant's instructional practice was impacted by the backgrounds of their students. Alex indicated that he felt the need to slowly transition his students from a more teacher-centered direct form of instruction toward the use of inquiry. He stated that the educational experiences of his student both at school and at home required him to utilize more traditional approaches at the beginning of the year. The observations of Alex throughout the year revealed that he utilized inquiry routinely, but Alex explained that he had taught most of these students the previous year. Alex commented that "I was able to take that facilitator role faster this year because I had them last year." It was during the end of study interview when Alex indicated that he would have to transition his new students. Both Stephanie and Tracy indicated that classroom behavior and maintaining discipline was an issue for them. This issue of discipline is an important mitigating factor to discuss as it has been referenced as a mitigating factor in multiple studies. The other reason student discipline is an important factor to mention here is that Stephanie and Tracy claimed that student behavior issues occurred for the same, yet opposite reasons. Discipline problems appeared to exist for Stephanie and Tracy due to the same school structure factor.

Extending beyond both the personal level and the classroom level, school level factors mitigated the interaction between beliefs and practices for all three participants as well. As mentioned above, Stephanie and Tracy each indicated that maintaining discipline was a problem in their classrooms. For both, the same school policies, ability grouping and common grade level pacing, precipitated this issue. Ability grouping was practiced at each participating school. At Alex's school, he was encouraged to alter his instruction and pacing to progress his higher performing students as far and deeply as possible. However, Stephanie and Tracy were expected to plan together and teach the same lessons each day. Tracy, who admittedly struggled to properly pace her lessons at times, struggled to maintain Stephanie's pace with her lower performing students who she felt acted up due to demands of the material. She also adopted more teacher directed methods in an effort to maintain discipline and keep up with the grade level pacing. Meanwhile, Stephanie indicated that her students behaved poorly because they were bored at the beginning of the year due to this school level factor:

> And the first semester, even though we had our students grouped according to their ability, they were having us still teach the same exact thing to all of the students. So we really struggled with that, because we spent eight weeks on addition and subtraction, and my students didn't need addition and subtraction at all….So they complained a lot.

And while Stephanie and Tracy were both struggling with this unforeseen consequence of common grade level pacing, Alex was benefitting from the lack of this policy at his school. Though Alex indicated that he felt the pressure to teach well, he also knew that he enjoyed the trust of his administration. Subsequently, while Stephanie and Tracy were forced to deal with the discipline problems which resulted from a school policy of common pacing despite ability grouping, Alex enjoyed the freedom of a school policy which permitted self-pacing. This single school policy issue both contributed to the implementation of teacher practices that were inconsistent with the Stephanie and Tracy's beliefs while allowing for the implementation of practices which aligned with Alex's beliefs. However, all three teachers also dealt with factors which extended beyond the control of the teacher or administration.

The final level of contextualization deals with community, state, or national factors that mitigate the interaction of teacher beliefs and practices. For these three teachers, the sociocultural backgrounds both of the teachers themselves and the parents of their students acted as an extra-school level mitigating factor. All three participants readily indicated educational experiences which were prevalent with traditional algorithms along a teacher-centered, direct instruction. However, even as these teachers strove to utilize student-centered, inquiry based practices in their classrooms, they not only had to overcome issues dealing with curricular resources, student behavior, and school policies, their instructional decision-making was also impacted by the educational experiences students received at home. All three participants mentioned that their students were exposed to the traditional algorithms at home. All three participants mentioned that they had to adjust their instruction in light of this influence. And this issue was also directly observed with all three participants.

Though the issues mentioned above dealt with common factors from four different levels of contextualization, there were three other significant factors which were common to all three participants which bear mention. All three of these factors were beyond the realm of school control. This lack of control or even input might have contributed to the impact they appeared to have on the participants as all three contribute to teacher stress. The most frequently mentioned factor was the end of grade testing. All three participants indicated various ways in which test scores impact their instruction. Stephanie acknowledged planning and teaching the measurement unit poorly "because we were trying to get everything in before they took their end of grade test." Tracy expressed her concerns that her students might grow tremendously that year but that growth would not be revealed due to the lack of a pre-test. And Alex very clearly expressed that he would not teach in April because he was busy getting his students ready for the end of grade test. And yes the end of grade is controlled completely by the state and completely beyond the control of the teachers. The impact of the end of grade test was closely associated with another important factor: time. All three teachers also indicated that they simply lacked the time to plan and teach their students as well as they would like. The state mandates that schools meet for 180 days each year. However, schools are able to adjust their schedules and budget more time for particular subjects. However, Stephanie and Tracy both indicated that their schools commitment to a reading grant took some instructional time away from mathematics. Alex did not complain specifically about the amount of time provided each day for mathematics, but rather stated that it simply was not possible to cover everything that was going to be on the end of grade test. And Alex had the higher performing students. A final and again related factor was the global economic recession which, throughout the course of the study, had become a central concern worldwide. This final factor represents the most encompassing factor level: global. The global recession pushed financial concerns to the forefront of everyone's mind and caused tremendous stress for many. These three participants and their instructional practices were not immune to its impact. Alex mentioned specifically that "we use money a lot because it's so important to these kids." Stephanie discussed the financial burden that many of these students feel. Tracy changed one specific lesson because a student commented that her mother could not afford to buy Skittles. But perhaps the most striking impact of the recession was the obvious concern expressed by Tracy and her fears about losing her job. Tracy abandoned all thoughts of aligning her practices with her beliefs and focused strictly on getting her lesson plans turned in and being on the same page as the other third grade teachers. She abandoned her beliefs because "I felt my job was in jeopardy. I truly did. That scared me more than anything."

The range of contextual factors mentioned above present an array of ways in which the *CI Model* helped examine the changes in the beliefs of these teachers. This discussion also demonstrates the way in which data collection and analysis was guided by the model. As will be discussed in greater detail later, the *CI Model* also guided the investigation into the second research question which dealt with the extent to which these teachers held experimental views toward teaching. Without question, the *CI Model* proved to be an invaluable tool in this study. The model was so useful in fact, that it helped improve itself.

Revising the Contextualized Interaction Model of Teacher Change

The original *CI Model* that was used for the design of this study was described in detail in the Theoretical framework (p. 25). Please see this section for in depth descriptions of the model component. The discussion below will focus on the ways in which that original model was changed based on the findings from this study.

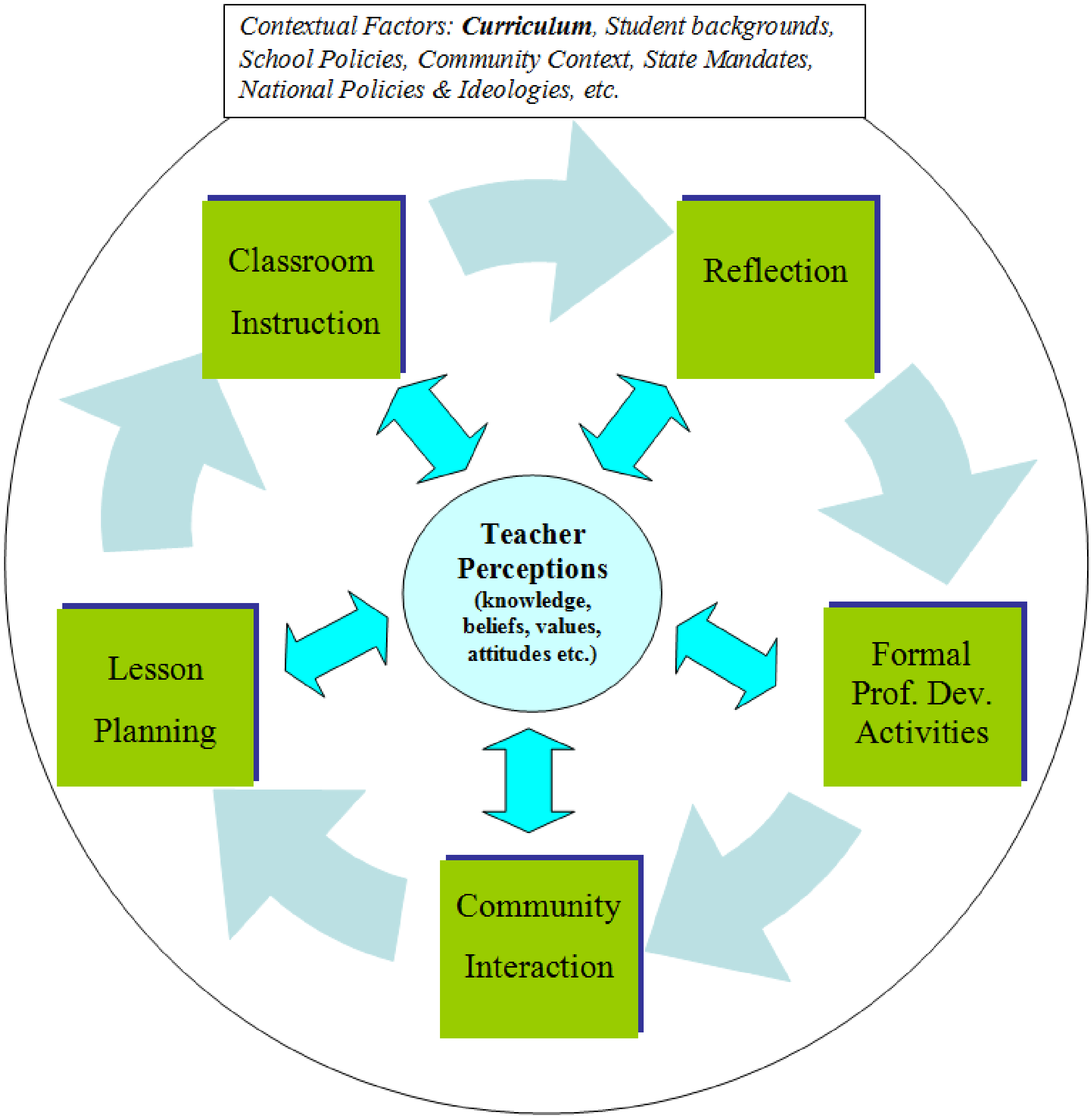

Figure 7 The Contextualized Interaction Model of Teacher Change (revised version, Neale, 2011)

The original model depicted curriculum as a contextual factor that might be no more influential than community context or school policies. However, curricular resources have been found to play a far more critical role in teacher change than the other contextual factors listed (e. g. Brown, Smith, and Stein, 1996). Some researchers have placed teachers' interaction with curriculum at the core of their models (e. g. Remillard &

Bryans, 2004). And in this study, the curricular resources were a profound contextual factor that mitigated the interaction between these teachers' beliefs and professional development activities, planning, instructional practices, and reflection. Unlike the other contextual factors, curricular resources played a role in every form of professional activity observed. Curricular resources were found to mitigate the planning, the classroom instruction, reflection, and formal professional development activities of all three participants. The participants also indicated that their interactions with parents, modeled as informal social interaction, were also impact by curricular resources. If curricular resources were in fact found to mitigate the interaction between teacher beliefs and every professional activity, then that would explain why curricular resources appeared to play such an important role. The original version of the *CI Model* simply failed to properly convey the influential nature of curricular resources. The revised version of the model above represents the 'zooming out' of the contextual factors by listing the various levels in order away from the individual toward increasingly broad societal factors. A more visual representation might show these levels as concentric circles, though a computer manipulated form would probably be required, it would be an ideal medium in which the researcher could literally zoom in to focus on teacher perceptions or zoom out to focus on contextual factors. The primary contextual factor, the factor located most closely to the individual teacher would be curricular resources. And this key factor should deliberately encircle all five professional activities while other factors might be found to only interact with one or two specific professional activities. As was the case for these participants, this curricular resources factor impacted the planning and reflection because the curricular resources included assessments which were a key component of lesson evaluation. The curriculum, as was also the case for all three participants, can be connected to formal professional activities as well. In this way, the curriculum has the potential to play the most significant role of all the contextual factors since it's closely connected to the individual and can be involved in every professional activity.

Placing 'curriculum' in bold in the model certainly fails to convey the potential importance of this factor, and obviously, the explanation of the model plays an important role here. However it is important to note that the curriculum cannot be more than a contextual factor that impacts the interaction between teachers' beliefs and professional activities. Though curricular resources have the potential to powerfully impact every teacher activity, the teacher can control the degree to which they incorporate the curriculum. Researchers have noted (e. g. Rogoff & Chavajay, 1995) that teachers may transform curricular resources to fit with their beliefs. This phenomenon was observed in this study. Alex transformed his traditional textbook to encourage students to search for multiple approaches, and Tracy utilized the traditional vertical algorithm for addition on an open-ended, reform-oriented problem probing students to search for easy groups of hundreds, tens, and then ones. Subsequently, though this revised model emphasizes the importance of curricular resources, they are still viewed as a contextual factor. Even though the investigation into the first research question ultimately led to a refinement of the *CI Model*, the original model was critical to the endeavor to understand the interaction between teacher beliefs and teacher practice.

Two other changes were also made to the model. The first was a component name change from Social Interaction to Community Interaction. This change was made to more clearly indicate that this model component refers specifically to situations in which the teacher is interacting as a professional with any member of the community. This change to the model occurred in response to the ‘Math Night’ event attended by Tracy and Stephanie. This event clearly represented an important level of interaction with the community, but the event was rather formal and not social. These types of formal community involvement have become more frequent as of late, and the component name now reflects both formal and informal interactions with non-teaching community members.

The second change was to the title of the central component of the model. In the original model, teacher beliefs were listed as the central component. It was explained that, with regard to the model, teacher beliefs referred to the broadest definition of beliefs and included knowledge and values. In the literature review, mentioned was made of Philipp’s (2007) reference to the increasing importance of teacher perceptions in general. Philipp indicated that attitudes and other forms of perceptions which fell beyond the context of beliefs should be investigated along with knowledge, values, and beliefs. This study focused exclusively on examining changes in teacher beliefs. However, that examination uncovered the important role played by the motivation to change found with all three participants. Though this motivation was understood as impacting these teachers’ beliefs, it would be more appropriate to incorporate motivation as a form of teacher perception. This model component is also located at the center of the model to represent researchers’ inability to directly that component directly as is the case with all teacher perceptions. In light of this interpretation and Philipp’s remarks concerning the need for more research examining teacher perceptions in general, it seemed appropriate to place teacher perceptions at the center of the model instead of strictly beliefs. The *CI Model* was also intricately connected to the investigation into the influence of having an experiment view toward teaching which was the focus of the second research question.

Research Question #2

The second research question dealt more specifically with the predication that having an experimental view toward teaching would relate to changes in teachers' beliefs:

> *Research Question #2: To what extent does having an experimental view toward teaching account for changes in beliefs?*

Based on theory, previous studies, and the *CI Model*, it was hypothesized that teachers who viewed lessons as experiments, deliberately tested their beliefs about teaching, and evaluated lesson successfulness in terms of student thinking would demonstrate a greater shift in their beliefs toward a reform orientation. The beliefs survey was used as the primary tool to assess teacher beliefs, but interviews, observations, and co-planning sessions were used for triangulation. As discussed above, these various measures allowed for clear images of these teachers' beliefs to be acquired. A View toward Teaching Survey (Appendix D) along with the interviews, observations, and co-planning sessions were triangulated to determine the degree to which the participants held experimental views toward teaching. No previous studies had attempted to measure these views, and doing so proved difficult. But as discussed in the Results Chapter, Alex appeared to have the strongest experimental view toward teaching followed by Stephanie. Tracy's search to clarify her views toward mathematics, teaching, and learning placed her as having the weakest experimental view of the three. As difficult as it was to clearly demonstrate the degree to which these teachers held experimental views toward teaching, the contextualized factors which impacted the interaction between their beliefs and practices posed the greatest hurdle. This hurdle was not overcome. As will be discussed in greater detail below, the tendency for these teachers' beliefs and practices to depend on contextual factors made measuring changes in their beliefs exceedingly difficult. Difficulties in measuring changes in beliefs resulted in an inability to determine the extent to which having an experimental view accounted for these changes. Overall, contextual factors accounted for the apparent variance in teacher beliefs more so than having an experimental view accounted for changes in beliefs.

Based on the results of the beliefs surveys, the beliefs of these teachers altered radically throughout the course of the study. As shown in *Tables 10, 11, and 12*, these teachers weighted their views toward mathematics, learning, and teaching in strikingly different ways over the course of a single year. In general, teacher beliefs have been slow to change (e.g. Llinares & Krainer, 2006; Philipp, 2007; Swan, 2004, in press; Thompson, 1992). Rather than assuming significant changes in the beliefs of these teachers, it appears far more likely that the variance in the survey responses was mostly due to the contextual factors discussed previously. There was one general tendency noted. The participants tended to decrease the weight given to the transmissionist view over the course of the study. Swan (in press) noted similar tendencies among his participants utilizing the same survey. This trend was hypothesized and certainly hoped for, but the differences between surveys were far too small and inconsistent with very high standard deviations. The trend was not delineated well enough to relate to the teachers' experimental views. As strongly as the results supported a clear response to *Research*

Question #1, the findings provided disappointingly little information to inform a response to *Research Question #2*. However, an additional goal for this study was to reveal data which might not have been relevant to either research question but still significant. That study purpose was achieved.

Other Relevant Findings

The most significant finding which fell beyond the purview of the two research questions revolved around the issue of inconsistencies between beliefs and practices. Multiple researchers have observed teachers who have implemented practices which contrasted strongly against their professed beliefs (e. g. Hoyles, 1992; Polly, 2009; Sztajn, 2003). As discussed in the literature review, some researchers have concluded that certain beliefs are sometimes given higher priority over other beliefs which account for divergent practices (e. g. Skott, 2001). Some researchers have argued that reform based professional development has provided teachers with the knowledge of the types of beliefs they are *supposed* to have. These teachers might claim to hold beliefs that align with reform based practices without actually altering their practices (e. g. Lester, 2002; Polly, 2009). However, other researchers have noted that contextual factors might account for apparent inconsistencies (e. g. Hoyles, 1992; Raymond, 1997; Swan, in press). The findings presented in this study shed significant light on this issue. As presented in the results and depicted in the *CI Model*, contextual factors were found to influence the practices of all three participants. The findings presented here consistently revealed an interactive relationship between beliefs and practices that was mitigated by an array of contextual factors.

The participants in this study received formal professional development aimed directly at improving their ability to utilize reform-based practices with an emphasis on the use of inquiry, problem solving, and a focus on student thinking. All three teachers indicated a strong desire to utilize these reform-oriented practices, and on multiple occasions, all three teachers implemented practices which aligned with these professed beliefs. But all three teachers were also observed implementing very traditional practices as well. Data triangulation along with the use of the *CI Model* demonstrated that contextual factors could account for these inconsistencies. The factors which were observed included curricular resources, student backgrounds, school structure policies, the mathematical backgrounds of parents, a desire to maintain pacing for state mandated assessments, and the worldwide recession. As Skott (2001) argued, beliefs do not change based on the situation. Actions however do depend on the situation and multiple contextual factors were noted on every occasion in which inconsistencies were observed. The support found for the *CI Model* in this study along with the preponderance of triangulated data support Philipp’s 2007 assertion that researchers should assume inconsistencies between beliefs and practices do not exist. That assumption was made for this study which helped provide for the revelation of the contextual factors. Undoubtedly, some teachers might claim to hold beliefs which they in fact do not hold, but this study has helped to confirm the assertion that researchers should focus on determining why teachers’ practices appear inconsistent with their beliefs. The endeavor to do so will certainly prove to be an important component in the continued effort to reform mathematics education.

Another more minor yet important conclusion from this study dealt with the use of traditional algorithms. All three teachers utilized the traditional algorithms exclusively. During the summer sessions of professional development, the participants designed lessons involving open-ended problem solving, multiple approaches, and the use of inquiry and student centered practices. These teachers were observed using all of these methods, and all three worked to encourage students to use multiple approaches when solving problems. Specific attention during the summer professional development was also given to increasing teacher understanding of traditional algorithms. However, the observations revealed that these teachers were only comfortable using the traditional algorithm. Even when the *Investigations* lesson specifically called for expressing addition horizontally and utilizing the commutative property, Tracy was observed performing the traditional vertical addition algorithm. Alex requested that the researcher explain and show his class a few different algorithms for multiplication, but with that single exception, all of these participants focused exclusively on the use of the traditional algorithm. This issue of the use of traditional algorithms, inconsistencies between teachers' beliefs and practices, and the responses to the two research questions led to some obvious implications and areas for future research. These two topics are addressed in the conclusion of the paper along with the study limitations and the discussion topics noted throughout the results.

CHAPTER 6: CONCLUSION

The conclusion will begin with the study limitations. The study implications will then be discussed along with a review of the areas for future research. The paper will conclude with a very thorough discussion section which highlights several excerpts from each participant that provide salient examples of the benefits of designing the study using the *CI Model*.

Limitations

One important limiting factor was that participants were selected by their principals to participate in this professional development program. In addition to being selected for the program, participants were invited into the study, with two potential participants declining to do so. It would have been unreasonable to attempt to account for the impact of these sampling effects. Being selected by principals for the program could have impacted motivation and engagement in a negative or positive way. Since the purpose of this study was to examine and attempt to explain why changes in teacher beliefs and practices occur, it may or may not be important that the participants were selected to participate and that they ultimately volunteered. However, an unexpected limitation of the study could have been a result of this sampling issue. All three participants presented strong motivations to teach in ways that contrasted strikingly to those to which they were exposed as students. This motivation was a significant commonality among the participants. The principals may have selected these teachers for this professional development program in part because they had these strong motivations. This commonality was an example of why this sampling issue may be an important one to consider when interpreting the results of this study.

Another important limitation is the use of strictly early elementary teachers in the study. It's possible that changes in beliefs and practices occur differently for typical middle and secondary teachers than for the typical elementary teacher. Several studies have found significant differences in the beliefs, practices, and teacher knowledge of early elementary, late elementary, middle, and secondary mathematics teachers (e.g. Ball, 1990; Quinn, 1997; Rech, Hartzell, & Stephens, 1993; Wilkins, 2008). Based on these studies, this limitation was significant and the findings from the current study might only apply to lower elementary teachers. Lastly, only third and fourth grade teachers were selected. Limiting the participants to two, consecutive grade levels could further limit the generalization of the findings.

Lastly, there are some important limitations of the *CI Model*. Other models (e. g. Remillard & Bryans, 2004) have centered around constructs other than teacher beliefs. Locating beliefs at the heart of the *CI Model* placed an inherently emphasis on beliefs when other researchers would argue that the central components of those models should be given greater consideration. The beliefs of the participants in the current study were given greater emphasis than would be the case if other models were used. Similarly, the model limited the professional activities to only the five model components. However, it is a distinct possibility that these teachers engaged in professional activities that should have been categorized within components that are missing from the model. The fact that the *CI Model* was used to guide this study acted as an important limitation in itself. As noted in the conclusions, the potential impact of curricular resources was not represented in the original model. Subsequently, curricular resources were not attended to as carefully as they would be if the study were designed using the revised model. Valuable data focused on the role played by the curricular resources may have been subsequently overlooked. The current study and its conclusions were similarly limited due to the use of a non-electronic model. Designing the study using this static model may have limited the degree to which the researcher was able to zoom in and out between the psychological and sociological perspectives. The limitations of the model depiction may have resulted in reflective limitations in data collection. These limitations point directly toward important areas for future research.

Implications and Areas for Future Research

Use and Testing of the CI Model

The most important implication of this study is also its strongest contribution: the *CI Model*. This model not only appeared particularly accurate, but it was also a critical tool in this investigation. The model should probably be converted to an interactive computer animated version in which researchers can literally zoom in and focus on the individual, psychological component of teacher beliefs and perceptions or zoom out beyond the professional activities to focus on the sociological contextual factors. Either way, the *CI Model* provides a framework for the continued investigation into all the variables that impact teaching and encourage or hinder teacher change and implementation. Researchers investigating teacher beliefs, teacher practices, teacher change, teachers' professional activities, the interactions between these components, or the contextual factors which mitigate these interactions should utilize a model, like the *CI*

Model, to frame both the psychological and sociological issues involved. In addition to utilizing the model as a study framework, these models should also be used to help frame, organize, and structure the array of educational research pertaining to the model components and factors. This study has shed important light on factors which appear to encourage or inhibit the implementation of reform-oriented practices. As findings are verified, they should be represented in the model. Again, this process is only achievable using computer animation. There are several options for the next stage of model development and testing.

Contextual Factors

Support had been provided prior to this study for the potential impact of contextual factors on teacher practice. Many of the findings from previous studies were confirmed in this study, but this study now provides a theoretical foundation for those findings. The portion of the model that represents the impact of contextual factors on teachers' professional activities is ready for large scale testing. Philipp (2007) called for the creation of more accurate models and the need for testing of models using large samples. The *CI Model* and the findings from this and other studies support the hypothesis that contextual factors can encourage or inhibit teachers' use of reform oriented practices and teacher change in general. As will be discussed later, many of these contextual factors can be easily controlled. The *CI Model* should be used to structure a large scale factor analysis to test the degree to which specific contextual factors mediate the use of reform oriented practices in teachers professing reform oriented beliefs. This quantitative study should include measures of the degree to which teachers feel impacted by a range of contextual factors as well as measures of teacher beliefs and practices.

The findings presented here support the premise that circumstances can drive teachers to enact practices which deviate from their professed beliefs. More importantly, these teachers were all driven to enact reform orientations toward instruction, but controllable contextual factors led to their reliance on traditional teaching methods. This study helps leads researchers and policy makers towards identifying the factors that support teachers' efforts to implement reform-oriented, research based practices. The vast majority of the contextual factors which appeared to restrict these teachers' use of reform oriented practices can be addressed. It would of course require that greater funds be devoted to education, but the amount of time allotted for planning and reflection and the opportunity to engage in professional development as part of the regular school day are all issues which can be easily, though expensively, addressed by policy makers. Another important factor is the impact of state mandated testing. These teachers were all motivated to teach to the test which can support improved instruction but only if the test is well designed. Already a focus for organizations designing those tests, this study supports the need for assessments to minimize the content covered while maximizing the focus on critical thinking. All three of these teachers traded the use of best practices to cover the content on the end of grade test, but the use of traditional methods will not help students gain those critical thinking skills. One final contextual factor which could be easily addressed by administrators deals with the policy of requiring grade level teachers to match pace with each other. Administrators should only consider utilizing this policy if they are confident that the backgrounds of the students in the various classes are virtually identical which is extremely unlikely. Teachers must be treated as professionals and encouraged to adjust their instruction best meet the needs of their students. Administrators should provide the planning time for these teachers to work in concert rather than mandating that they align their pacing. Finally, all three teachers noted the impact of the teaching of traditional algorithms at home. Teachers should work within their community to help educate parents about the differences between reform oriented practices and tradition teaching methodologies. Parents need to understand the goals of classroom instruction as well as the pitfalls of traditional methods. Schools, including one of the participating schools, have started hosting Math Nights to create platforms for educating parents and engaging the community. This type of event falls directly into the community interaction component of the *CI Model* and provides educators with an opportunity to impact community level mitigating factors. Interaction between schools and their communities has always been encouraged. The *CI Model* represents the interaction between this mitigating factor and teacher perceptions, and the findings from this study demonstrate ways in which the community can both encourage and inhibit reform-oriented practices. Very little research has been conducted studying the impact of the interaction between teachers and the community. This arena represents an important direction for educational research in mathematics.

Traditional Algorithms

A third and more specific implication involves the use of traditional algorithms. There has been some debate regarding the teaching of traditional algorithms, though it appears as if the proliferation of THE traditional algorithms seems to have won out. The findings presented in this study confirm those which researchers (e. g. Mewborn, 2002;

Wilkins, 2008) have noted for quite some time; that teachers tend to know the traditional algorithms but lack a strong understanding of the mathematics behind them. A significant problem inherent in teaching the traditional algorithms is that teachers are in essence forced to abandon the problem solving ideal of encouraging multiple methods. Further, as was observed with Alex and his students, relating alternate algorithms or even showing the traditional algorithm using different notational features might require teachers and students to gain a better understanding of these algorithms. Improving teacher understanding of the traditional algorithms was not a specific goal of the professional development program, nor was this study focused on identifying teacher understanding of these algorithms. However, it was readily apparent that these teachers' understanding of the traditional algorithm impacted their instruction. This issue of teaching only traditional algorithms should be revisited.

Ethnographic Study

The current study failed to illuminate the relationship between having an experimental view toward teaching and changes in beliefs. Part of the reason for this failure was that more qualitative data needed to be collected to fully reveal the nature of this relationship. An ethnographic approach could have provided that data which is why that particular recommendation is made here. The proposed qualitative study should be conducted in tandem with the pathway analysis to provide qualitative data that clearly describe ways in which contextual factors mediate teachers' professional activities. This study should be conducted with just a few teachers and utilize an in-depth ethnographic methodology and utilize grounded theory as the theoretical framework for the analysis. Researchers should shadow participants for several days throughout a school year to describe the mediating effects of contextual factors. The current study utilized multiple in-depth observations and interviews throughout the year, but as noted in the findings, important demonstrations of mitigation occurred which were not observed. Ethnographic shadowing is required to truly document the mitigating effects of contextual factors, and the use of grounded theory to frame the analysis would help demonstrate the efficacy of the model. These proposed studies would combine to provide invaluable information for administrators and policy makers. The combination of these studies could help identify the policies that encourage good teaching as well as those which inhibit it. Some of those factors seem were identified by the current study and represent another important implication.

Discussion

As mentioned throughout the Results Chapter, there were multiple situations in which data were collected and analyzed that provided valuable insight on the participants, use of the CI *Model*, benefits of focusing on the degree to which participants held experimental views toward teaching, and examples of valuable interview techniques. These raw pieces of data and short analyses were too lengthy and unfocused to include in the results section, but still offer a valuable way in which the study can contribute to the literature. The discussion section below provides the reader with access to that data and analysis.

Alex's Baseline Data

The segment below came in the first few minutes of the baseline interview with when he was explaining having to re-teach multiplication.

[A]: I know they've been taught this stuff. We (teachers in general) do too much on the surface and we move on. It's not taught to mastery. You can't get anything to mastery and therefore there's no real solid understanding until who knows when that hits I think it's different for every child. There were times in high school when I finally put things together… I was never taught patterns and now when I teach these I'm like ‘I wish someone had told me this’.

And regarding how he was taught:

[A]: It was definitely memorization. It was a rule. You followed it and you don' know why you just do it because [laughs] that's the way it was taught.

But when asked about his own teaching practices:

[A]: When I first started teaching, I thought that my job was to cover the objectives for that day. Make sure that they could spit it back out and retain it to me and know that they had something they could leave the classroom and go home and tell their parents 'I learned blank today’.

Another segment of the interview, which was instigated by referencing Alex’s responses on the Beliefs Survey (Appendix B), revealed the complex way in which contextual factors can interplay with beliefs and practices. Alex demonstrated a Connectionist view toward teaching mathematics by indicating a 70% agreement with the statement that “teaching mathematics is… A non-linear dialogue between teacher and students in which meanings and connections are explored verbally, where misunderstandings are made explicit and worked on”. When asked about this response, the excerpt below followed:

[A]: Math isn't linear. It's not 'okay, tell me what to do’. It would be so much easier if teaching math was linear, but it's not. That's part of being the facilitator and the script to include going off script. It's okay to get the wrong answer because you're doing math. Where do we push or prod to get the right answer or what direction we need to move in.

[R]: [knowingly] So, this is how you were taught?

[A]: Definitely not?

[R]: So why are your views so different than those that you were exposed to growing up?

[A]: I guess when you look back and realize you didn't get it until later, until you taught it. I'll say that I wish someone had taught me that way, and I don't want to be a teacher that kids say that about.

[R]: Did you have that facilitator view in your first year or during student teaching?

[A]: It's in the back of your mind that's what you want to work toward, but you're so focused on getting stuff done. As you get more experienced, you learn that you don't have to listen to the principal all the time as long as you get your job done. That first year, you're like I gotta do it this way, this is the book they gave me.

Alex made other comments during the interview which revealed the interaction between curricular resources, student backgrounds, and instructional practices:

[A]: When you take on a facilitating role, you don't plan because you don't know…you do plan the things you want to hit on… To be a true facilitator, you have to go where the class is going. You have to gauge their understanding and where you have to do the teaching....I always have a goal.

[R]: How do you get that goal?

[A]: My goal is whatever they're (the book) is teaching that day. So each day the book provides the pacing guide and a resource…I read the goal and then I put it into student words.

Alex indicated that the sociocultural backgrounds of his students impacted his instructional practices:

[A]: We have a diverse population with a high percentage free and reduced lunch so we talk a lot about money because they understand it and recognize how important it is… It's not a good thing that they worry about money but it is something that interests them and is important to them.

Alex also indicated that sociocultural constructs on a national level impacted his instructional decision-making:

[A]: You gotta have a grade in the grade book. I don't agree with it. I don't think there should be grades. I think it should be understanding of conceptual knowledge, but that's a whole ‘nother shift. Grades are something people understand. You gotta have a grade in the gradebook to show mom and dad what Johnny's doing in class. You gotta have something to cover your hiney if they don't do well.

[R]: Is that something you're told to do or is that you're idea.

[A]: You're definitely responsible for putting grades in the grade book and coming up with a report card. I wouldn't say I was told to do it, but it's expected and everybody does it… When I taught lower elementary, you grade by goal and we get away from that in third and fourth and I don't understand why because you can have a good place value understanding but suck at shapes. (For example) Johnny is great at perimeter but he can't do his multiplication facts to save his life, but he made a B but mom and dad are happy. What do you mean he can't do it, he made a B? That's the problem you run into with holistic grading.

Alex's views toward mathematics and teaching mathematics along with his practices were clearly impacted by various contextual factors: the backgrounds of his students, the school culture, and the national culture as well as the end of grade test. Alex also claimed that the standardized end of grade tests impacted his planning and instruction:

[A]: The sad thing is, from April on, you don't teach hardly any new material because you are reviewing so that part of the book may not get taught. You're going to have to teach it but not in a facilitating fashion. You're teaching it as a multiple choice problem… I hate that but my butt's on the line because it says "[Alex]'s scores" and if they're 1, 1, 2, 2, …" [The principal]'s going to have me in the office saying 'what are you doing?'

[R]: You feel like your butts on the line?

[A]: Absolutely, even though they say that's its not, if I don't produce…It's a business! School's turned into a business model-you've got to show production.

[R]: Do they consider the scores of the students from the previous year?

[A]: You gotta show growth. You're not expected to turn water into wine, but you better show growth. In fourth grade, they're proficient or not but you can still show growth. third grade has always been able to show growth because they come in from second grade and they take that EOG pretest and they bomb it. You can make yourself look like teacher of the century because they've made so much growth. It's harder in fourth grade because that growth catches up to you.

Alex’s Observations

Observation #1. During the baseline interview, Alex had indicated that his typical lesson script included having a goal provided by the curricular resource, using a problem to start the lesson, letting students work in groups to solve the problem, have groups share their responses with the class, and Alex’s script included going off script by allowing the lesson to progress based on student interest and understanding. This first observation followed Alex’s typical script very closely. He put a problem up in front of his students who started working on it immediately. The problem asked students to find the pattern which was the pattern of squares of counting numbers. The students had obviously become accustomed to working alone on presented problems before working together on them in groups. Alex maneuvered throughout the classroom listening to student discussions, answering some questions, but asking many more than he answered. The students seemed comfortable explaining how they approached the problem while the class was listening, but Alex remained in front of the class to summarize students’ ideas. Alex did let one group discuss ‘square number’ and asked “what’s a square?”, but Alex did not pursue the squares of numbers. The discussion regarding the patterns focused on adding increasing odds and Alex asked students to recognize the ‘factors’ of each term. When asked, during the post-observation interview, about his purpose in choosing this problem and how he anticipated students handling the problem, Alex responded that he thought a few students might pick up on the square numbers topic but only because the class had discussed it previously that year. After the introductory problem, Alex reviewed the homework for a few minutes.

The introduction into the formal lesson for that day followed after a quick stretch break. Again, Alex began with a problem on which students worked alone and then in groups with Alex walking around the room asking students questions about how and why they got what they got. The problem asked students to represent $2.25 in multiple ways. When asked about the lesson goal afterwards, Alex indicated that he wanted his students to work with mixed fractions. He did not indicate that developing number sense was a goal. Of the three groups of students, two were talking and working together a great deal while the third group was relatively quiet. Alex had a student from one group explain that group's solution to the entire class and used the opportunity to review terminology. Alex then moved onto another similar problem and instructed students to find a partner to whom they had to explain their approach to the problem. Students were having difficulty really explaining their thinking and reasoning, so Alex took time to explain that 'explaining' meant telling your partner how you got your answer and what you did to get your answer. Alex extended this problem for the remainder of class before reviewing the lesson and assigning homework which was a variation of this mixed fraction with decimals problem. Alex noted that the goal of the lesson was to work on mixed fractions. Alex commented later that he stayed with this problem for a while because he could tell his students were having trouble with decimals and equivalent fractions.

During the post-observation interview, Alex indicated that he felt the lesson was successful overall. He acknowledged that he would need to revisit decimals and equivalent fractions again based on the understanding he observed during the lesson.

However, since Alex is fairly familiar with the spiral nature of the math program and the lessons themselves, he knew he would have opportunities in the future to address both. Alex indicated that students' correct use of terminology and ability to identify and define a mixed number was another indicator of lesson success which corresponded with his goal for that lesson. Another indicator was that students were engaged and "focused on math for the entire time". These comments fit with the measures of lesson effectiveness that Alex expressed during the Baseline Interview. Throughout this lesson, Alex made significant use of the timer. Alex had not mentioned that he closely monitored the time during his lessons, but he did mention that there was not enough time to cover the entire book in one year. Alex may have been implying the importance of time on task when he expressed the importance of student engagement. However, Alex also commented that the lesson from the previous day on writing numbers up to a million had flopped because "the kids just weren't into the lesson" which reiterated Alex focus on student engagement. Alex also stated that student performance on the individual assessments that they will be taking in the future would act as another important indicator of lesson effectiveness.

With the exception of the potential emphasis of time on task as a potential indicator of lesson effectiveness, this first observation of Alex aligned extremely well with the lesson script and teacher beliefs that Alex professed during the baseline interview. Many of the instructional practices which he described were evident throughout the lesson, and it was clear that the students were accustomed to these lesson activities which indicated that this lesson was not abnormal. Later Alex expressed that he had taught many of these students last year in third grade and that having them for a second year in a row made it very easy to establish consistent procedures. This observation was conducted in late October, almost two months after the school year started, so ample time had been provided for these procedures to become routine. No new themes emerged during the observation or post-observation interview.

Observation #2. The second observation took place in mid-November and included a co-planning session in the morning prior to the classroom lesson observation. Based on the *CI Model*, observing and/or co-planning lessons were included in the original study methodology. However, after the Baseline Interviews and the first round of observations, it became apparent that the classroom lesson observations would be more informative if the planning sessions for those lessons were observed in addition to conducting the post-observation interviews as well. It was for this reason that the attempt was made to meet with Alex to observe his planning session on the same day, strictly for convenience, that a classroom observation was scheduled.

Alex did not plan his mathematics lesson in conjunction with the other fourth grade team members. At Alex's school they grouped students by ability for mathematics, and Alex worked with the students who had earned the strongest scores on the mathematics portion of last year's EOG. Alex was expected to push his students at a faster rate and to a deeper depth than the other teachers. He subsequently tended to plan his lessons on his own. The researcher had intended to act solely as an observer during this first planning session with a focus on identifying a typical planning process or design for Alex. But the discussion topics which emerged addressed a diverse and interesting range of issues and exemplified the need for a model of teacher change which incorporates the range of professional activities and factors that interact with teacher beliefs to influence teacher practice. This single planning session would include every component of the *CI Model* for teacher change while also revealing the impact of curricular resources.

The planning session began with Alex indicating the impact of the spiraling nature of the curriculum and assessments. He explained how he utilized assessments to alter his instruction.

[A]: We did a lesson on rays, line segments, lines. That's a newer topic that we haven't spiraled back through again so that would be something I would be looking for in the test to see if that's something I need to spend more time on or it's good to go.

[A]: You don't teach to mastery everyday…because that's just the way the program is written, but you do get back to it I would say every six to eight lessons

[A]: What I'm really looking for on assessments is the new things. Like I will be looking for this (points at problem on assessment) associative property and working inside the parentheses because we did cover that the other day and we talked about, you know…it matters how you group your numbers to get a certain sum, product, or anything. We did basically just working inside the parentheses.

Alex then revealed that his understanding impacted his instruction. The researcher had indicated surprise that a problem dealing with squaring a number was on this third grade assessment.

[A]: We teach squared numbers in the third grade because they know that a squared number just means a number times itself.

[R]: Do they ever ask or do they ever talk about why it's called squaring?

[A]: We talked about an array and a square means the same. Other than that, no. But I taught it as an array and a square means that one side is the same as another side. So we did it like that.

Alex also reiterated that his typical lesson script included going off script. He discussed ways in which he would need to differentiate his instruction due to the spiraling nature of the curriculum and the understanding of his students. In this same excerpt, he also reaffirmed his non-transmissionist view toward mathematics teaching.

[A]: But see this is the one thing that I don't know if this, if *Investigations* would be better because I go from percents to adding numbers with more than three digits which are totally different and probably something that they're going to fly through. So basically that day will be a boring day in math... to ME because (trails off).

[R]: Is there any reason you don't just skip it?

[A]: Yeah because I'm afraid there's somebody in there that just doesn't have it yet…What I usually do on days like that is I'll make the problems into words problems or…I'll extend the activity. Like the other day we did multiplying two-digit numbers by single-digit numbers and that was pretty easy. But like the associative property, I gave them a product and told them they had to come up with the integers to make an equation that equaled 90. So they were creating their own problems as an extension of just solving problems. So you know. I do stuff like that. Sometimes I have a stack of number cards and I'll just pull out...[as if speaking to students] “you gotta pull out seven numbers. You pull out eight numbers. Now arrange this into an equation.” So things like that.

[A]: The other day I found this problem on [resource website]. It was a three-digit plus three-digit number and you had to get a three-digit number, but you could only use numbers one through nine, and you could only use that number one time. Dude, I worked on that problem...I never did solve that. I worked and worked, and they worked and worked we were like 'huh?' We'll probably hit that again when we do the three digit numbers.

After these preliminary discussions, Alex reviewed the key topics that he was planning on covering that year. A lesson on division which Alex had recently taught provided a clear view of Alex's focus on student thinking. But this discussion which began with Alex recalling a lesson on division went on to include several other issues. Alex affirmed that he viewed himself as a facilitator and that he held a discoveriest view toward teaching mathematics. He also reiterated his focus on preparing his students for the end of grade test. Furthermore, Alex indicated that he benefitted from two facets of the school's structure. He indicated the potential benefits of working with the higher performing students at a school that groups students by ability, and he also demonstrated the benefits of feeling trusted by his principal. And though other issues would be discussed later in the interview, those mentioned here were conveyed during just a fifteen minute time period.

[A]: When we were doing division, I counted out a hundred objects and … What we did was I had them in stations and they were switching and in each station putting them into equal groups. And I didn't really care if they got the right answer. I just wanted to see what their strategy was. So we were talking about strategies for dividing things out.

[R]: Can I ask real quick why you were just trying to look at their strategies? Why that's what you were looking for?

[A]: Because I wanted to see how they wanted to do division. What ways I could teach it, to make sense to them.

[R]: Okay, this is one of those little moments (Alex laughs and says “Oh”). So, we're going to go ahead and capture this guy. Tell me your thought process here.

[A]: 'Cuz instead of doing just an algorithm, or teaching it that way, I wanted to see, make, kind of like that moment with them of how to divide, what actually dividing is. And we got into it with the hundred counters that I had out.

[R]: But it sounds like you weren't just telling them what division is.

[A]: No. I just put 'em back there and said "you've got to divide these into equal groups. I don't care how you do it". Some kids built arrays...They found after they built it, they knew it was an array because, you know, it was a square, rectangular shape. And some kids divided it out "me one, you one, me one, you one". And then they came up and they were talking about their strategies.

[R]: They clearly had some idea what division was?

[A]: Yeah. I knew they understood what divide meant, because they've put things into equal groups since kindergarten.

[A]: One of the kids asked "didn't that take a long time for you to divide out or to give a hundred pieces?" And I was like "yeah, that's a good question. Is that time efficient?"…I said "If you had a group of ten year olds at a pizza party and they're going wild like you guys do and you wanted to get out of there, would you do it that way? Well, no."

[R]: And they were dividing a hundred into groups of…

[A]: Whatever they wanted. I didn't care. They had a hundred and I just said they have to be equal groups. Now I know that's not time efficient and that's kind of what we came up with. We need to do things time efficient. I said "that's not a time efficient way. That's like if you're on your EOG, hope to God you're not going to draw ten circles or a hundred things and then start marking them off.”

[A]: So we got into that a little bit and that was kinda...I was glad they realized, and then they thought well you know probably the best way to do this was to find that missing factor. What factors and we…and [Alex's principal] was in here observing me and we got into factor trees and they're like "well why do you need to factor? Why do you need to know the factors?"

[A]: I could've spent three days teaching that lesson because there were so many teachable moments.

[R]: And [the principal] was observing this?

[A]: Yeah, he's laughing back there.

[R]: Surely you were pleased that that happened?

[A]: Yeah, this a great group. And there's things I can do in this group and kind of facilitate and not have to teach a lot…which is what I want. I want them to be able to teach themselves because they're not always going to have somebody that…and that's what learning is is you learn how to learn.

[R]: So when you say "not have to teach a lot", do you not feel like you're teaching when you're acting as the facilitator?

[A]: Yeah, I mean you do. You just. You kind of put 'em in the right direction. I like for them to come up with things on their own because it makes it special to them. They remember it better than somebody just telling them.

[R]: So when you say "not having to teach a lot", do you mean not having to tell them a lot?

[A]: Yeah, right. I don't have to fill in all the blanks…I wouldn't change any of the activities. I would just have to be more rigid. Like if I put them in groups and told them they had to divide it out, I would have to give them a group. "How many equal groups?" or

[R]: If they (the students) weren't as strong?

[A]: Right.

[R]: I don't like saying simplifying the problem.

[A]: Well, yeah, but it is. You're taking it down a level.

[R]: Giving them more structure is probably a good way to phrase that.

[A]: Okay, "this hundred needs to be in ten equal groups instead of just throwing any factors out there I'm narrowing the base of possible answers.

As the discussion regarding ways to differentiate this division lesson continued, Alex went on to discuss the impact that parents can have on student learning if the parents are only familiar with the traditional algorithms. Alex then related this component of the discussion to a formal professional development session that he had attended a few days earlier. Based on Alex’s comments regarding the PD session, the researcher felt that it was important to clarify the issue which led to a professional discussion. Alex appeared to be somewhat conflicted regarding the teaching of multiple methods to students.

[A]: But a lot of kids' I guess parents have shown them the standard algorithm and they wanted to do that and... We kind of got into that discussion the other night with the [PD provider during formal PD session focused on Investigations] and she was like "Well, it's okay that they know that but you need to show them other ways." And I said "well, you do what's comfortable for YOU". And we kind of got into a discussion, and I was like "if I give you a problem and you give me a problem and we both solve it, does it really matter how we solve it?" And she was like "No." I think I said "we should show a bunch of different ways and let children choose what they want to use, but why does it matter that they have to show that way". And I kind of see both sides to it.

[R]: What I've gotten a lot of is kids are like "Don't show me another way. It'll confuse me." And usually the way I handle that is that if seeing it a different way confuses you, it does mean you don't understand this concept fully. These other methods, if you CAN'T do it that way, then you don't really understand this fully.

The researcher went on to show and discuss an algorithm for long division that a French exchange student had shown him. Though this algorithm appeared different than the typical algorithm used in the US, these differences were strictly organizational which exemplified the researcher’s argument.

[A]: Yeah, I agree with that.

[R]: But I've always felt like I've had that back pocket answer where kids are "well, why do we have to learn other ways?" Well, they're a bunch of different reasons but one of them is “Are you really trying to understand this concept or not?”, because if you don't want to see other ways, then you're not trying to understand it.

Alex went on to explain another challenge posed by trying to teach multiple approaches.

[A]: It's really hard to send…to teach these different methods, and kids understand the methods here but when they go home. There's some kind of black hole from school to home and then a parent only knows traditional algorithms, and yes, they can solve it, but they don't really know why or how they're solving it, and I think a lot kids have to know how something's done before they can actually do it or why it makes sense or why does that work. I guess you just have to meet them where their understanding is. If they're wanting to do traditional algorithms, then you have to explain traditional algorithms and why…

And again a little bit later…

[A]: Renaming numbers and coming up with short cuts or efficiency ways, I would say that's probably some of the new thinking. And I don't know. I haven't been teaching that long. I'm not saying it hasn't been taught. But I'm saying as far as understanding, I don't think that these kids have enough number sense yet to do some of these. So a lot of times you confuse. I think that's why *Investigations* is having so much trouble in third, fourth, and fifth now because they've been introduced to it, but they didn't really learn it that way and now you're making them show it that way and it's not working.

Alex was referring to some of the challenges that teachers using *Investigations* were facing. Though this entire interview lasted less than forty minutes, issues pertaining to almost every component of the *CI Model* were discussed. Alex's beliefs were referenced repeatedly. Alex's planning, classroom instruction, and formal engagement in PD were all discussed at length. Though he made no reference to informal social interaction, Alex indicated the impact that parents' mathematical experiences can have on his practices. He referenced the curriculum, school math program, and curricular resources repeatedly. Alex also discussed several contextual factors such as his students' experiences, the impact of the EOG and the schools' structure as well as administrative support. This single planning session clearly revealed the need for a mode of teacher change, like the *CI Model*, which incorporates the representation of the various factors that impact teachers' practices.

Classroom lesson observation #2. As now appeared commonplace, Alex began the lesson with a word problem that required students to recognize the need to correctly add two, 3-digit numbers by asking "The Panthers are playing tonight. Delhomme throws for 257 yards and team rushes for 323. How many total yards does the team have. Do you think they will win?" The students first worked alone for 5 minutes while Alex walked around the room examining their work and asking questions. He noted that some were having difficulty with the terms and significance of "rushing yards" versus "passing", so he clarified this issue for the class as a whole. Virtually all of the students used the traditional algorithm for adding which was the only method modeled in the text. After they'd work alone for several minutes, Alex asked students share their response with the class. Several students made errors, and Alex noted that almost all of those errors were the result of students failure to "carry the one into the tens place". Alex then demonstrated the traditional algorithm for students again and asked a prepared follow-up question: "If Stewart and Williams combined for 300yds, what combinations could they have each had?" A few different and very simple responses were provided by students, but Alex asked for another way to get the response that they each rushed for 150 yards in an effort to have students solve it using division. He used this approach to review the terms divisor and dividend but had indicated prior to the lesson that these terms were not a goal of the lesson. Alex tended to walk around the classroom while students were working independently or in groups but usually stepped to the whiteboard in front of the class when addressing the class as a whole.

After a brief stretch break, Alex introduced new problem: 15 x 3. One student showed class the traditional algorithm as the way they approached it. Alex asked several questions to encourage students to express that they weren't multiplying 1 times 3 but rather ten times 3. Alex also showed re-writing 15 as 10 + 5 to highlight distribution and emphasize that 10 was being multiplied by 3. Alex then asked students to try and do the multiplication in a horizontal form by multiplying 10 times 3 and 5 times 3 separately. During the post-observation interview, Alex would comment that the class became "dead" during this portion of the lesson. Since the class felt "dead" to him, Alex encouraged group discussion and engagement by having them determine which approach (traditional or this new method) was more efficient on a new problem: 35 x 7. He told his students that he was looking for them to have conversations about the different approaches. At this point, the researcher had a side discussion with Alex showing a slightly different algorithm that was set-up like the traditional algorithm but expressed 5 times 7 as 35 and then 30 times 7 as 210 which were then added. Alex had the researcher show this method for 15 x 3 to the class as an example of there being several ways to do things and that he'd never seen this method. However, when his students tried to use this approach with 35 x 7, most obtained 56 because the multiplied 3 times 7 to get 21 instead of 210. Alex and the researcher both observed the difficulties that the students were having. One student in particular referenced that the textbook explained “1 times 7 is 7” when multiplying 12 times 7 instead of 10 times 7 is 70. This student had practiced this algorithm repeatedly while doing his homework and seemed to really struggle with having to learn it a different way. The period ended without a definitive conclusion to the lesson.

During the post-observation interview, Alex noted that the difficulties his students had with this new algorithm during class indicated that they didn’t really understanding the traditional algorithm being used in the text. He noted that in this situation, the text was a poor resource due to the way the traditional algorithm was explained. Alex had very deliberately asked students to indicate their understanding of place value when using the traditional algorithm, but when the researcher and Alex examined the text, it was noted that the text failed to consider place value when describing the algorithm. Alex noted that a lot of people did not like this text since the text appeared to rely on repetition of traditional algorithms. Every elementary school in this system had adopted *Investigations* except Alex’s school. Alex stated that he liked the way the text spiraled through and that if you knew the curriculum, the program was okay. He also indicated that his use of inquiry was important, especially with this program. When asked about the lesson ending without any clear summary or outcome being achieved, Alex, much as he had intoned during the Baseline Interview, indicated that it was okay to leave lessons hanging like that and that he had become more comfortable doing so.

Observation #3. This observation occurred in early January just after students and teachers returned from their holiday break. Prior to observing this teaching episode, the researcher had planned a lesson which would be taught in a couple of weeks. The notes from that planning session will be discussed as part of Observation #4 which was the lesson being planned. The focus of the Observation #3 lesson was to insure students' basic familiarity with different types of graphs. Alex began by asking students to define display, data, and graph. After obtaining open responses from the class in general, Alex indicated to them that they seemed pretty solid with 'display' and 'data' but that they needed to work on 'graph' some. He then proceeded to ask individual student questions that required them to interpret the data displayed in the graph on the board. Every student was asked to provide a response at least once. With respect to line graphs, Alex explained that line graphs are used to examine things that change over time. He asked students for examples of things that change over time. One student mentioned the term 'rate', and Alex jumped at the opportunity to explain how a line graph of distance over time could be used to determine "how fast you were going." Alex then moved on to circle graphs using a problem from the text and again posed multiple questions to the class. While using the class's ethnicity as an example of a circle graph, an obviously impromptu diversion into percents and fractions developed.

After almost 30 minutes of posing these types of questions, Alex announced that he "wanted to see what they could do" and would be providing no further instruction. He had student groups of 3 or 4 volunteer to create a bar graph, circle graph, line graph, or pictographs. Alex was very deliberate about explaining to the class that he knew they didn't know exactly what to do but that he wanted to see what they could do. He perused the classroom and checked to make sure that each group included a title, key or legend, and proper type of graph. Throughout this portion of the lesson and the lesson as a whole, Alex notably avoided answering students' questions directly and telling them things and instead found ways to ask students questions that directed them toward their own answers. There was no opportunity for a reflective interview following this observation.

It is important to note that at this point the researcher was convinced that triangulation of data from the Beliefs and Practices Survey, the Baseline Interview, 3 observations along with an observation of Alex's planning session had clearly demonstrated that Alex professed beliefs towards mathematics and mathematics teaching and learning that were consistent with his instructional practices. Alex had professed a strong belief in the use of inquiry, a preference for student-centered instructional practices, placed a high value on student thinking, student discourse, and students' conceptions of mathematics, and promoted the use of relevant problem-solving and the use of multiple approaches. Alex had repeatedly demonstrated the skilled use inquiry to respond to students' questions and provide feedback. These techniques had been discussed and modeled during the summer professional development sessions, but it was apparent during these first 3 observations that Alex, as he had indicated during the baseline interview, had been using these techniques for quite some time. The observations up to this point had revealed instructional practices which aligned strongly with these beliefs and followed his typical script quite closely. Perhaps the most convincing evidence came in the form of the students' comfort level with the observed instructional practices. Alex's students were obviously accustomed to conveying their ideas to him and each other. Working independently and in groups on hard problems without being told how to solve them in advance appeared routine for these students. However, the co-planning session and observations of the planned lesson provided conflicting evidence.

Observations #4 & #5. As mentioned previously, Observation #4 covered the lesson which was co-planned just prior to Observation #3. The co-planning session involved working together to develop the lesson plans for a lesson of Alex's choosing. Based on work done during the summer professional development sessions, Alex chose a lesson in which he felt he could use the concept of making tens. In an effort to complete a thorough observation of the concepts being addressed in this lesson, the planning session began with a discussion of when these concepts would be addressed in the curriculum. Alex referred to several sections from the text which referenced the same concept of multiplying by multiples of ten. The researcher and Alex arranged the next observation to coincide with the instruction of this planned lesson which was scheduled for mid-January.

Alex had planned on beginning the lesson with a review of two-digit times single-digit multiplication in order to insure that students had a background that wouldn't interfere with their understanding of multiplying a two-digit number times a multiple of ten. Specifically Alex commented that he wanted "to make sure that they're not getting stuck on 25X3 when trying to get to 25X3X10." Alex examined a previous assessment which included problems requiring students to multiply a two-digit number by a single-digit number. He also planned on reviewing products of multiples of ten. Alex stated that this lesson focused on place value and powers of ten. The researcher felt that the commutative and associative properties of multiplication were intrinsic to this lesson but chose not to ask Alex about that issue since the end of grade test does not include those properties.

The overall lesson plan once again reflected Alex's typical script. Alex clearly envisioned himself directing the class by asking students questions as opposed to standing and delivering the information. He also indicated a preference for students working together and sharing their ideas. He again emphasized problem posing to engage students in individual and group work with an emphasis on students truly understanding at least one way of doing the problem. When asked about the ways in which he thought students might approach some of the problems he planned on posing, Alex commented that he would not "teach a method that he didn't understand." He went on to say that he "wasn't against new stuff", but rather, "new stuff without understanding how to use it properly." Alex also indicated that he felt the professional development work he had been doing had convinced him that "the way we learned [math] isn't the best way to learn it." He felt this was important because so many "people fail to recognize that they don't know the math." He also indicated that teachers tend to blame students for "not getting it" instead of taking the "burden of learning onto themselves." As would be expected using the *CI Model*, the researcher hoped to obtain a clearer vision of Alex's practices by aligning notes from the planning sessions with observations from the lesson itself and the reflective post-observation interview.

Classroom observation #4. Alex began the lesson with an unrelated problem which turned out to be pretty easy for most students: "If Mr. [Alex] exercises for 1 hour and 50% of the time he's on the treadmill, 25% is stomach workout, and 25% is lifting weights, then how much time does he spend on each activity?" After letting students work alone on the problem for a few minutes, Alex asked "what information would it be good to know?" Alex recorded student comments on the board like "15+15 = 30 minutes”, “60minutes = 1hour”, etc. He then had students continue to work alone until he felt everyone in the class had a good handle on the problem. He then announced "I might make this problem a little harder tomorrow". After this quick introductory problem which was not directly linked to lesson objectives, Alex began the lesson by posing a problem as planned. Alex began with a preamble which seemed like something students had heard before: “I'm going to put a problem on the board that you haven't seen before. You don't have to be perfect today. You don't have to get it right, but I want you to work alone.” Alex then wrote 34x20 on the board arranged vertically. Of note, Alex had planned on reviewing single-digit times two-digit so this problem did represent a departure from the lesson plans, but based on students’ reactions to this problem, he may have already felt that his students were secure with this skill. Several students indicated that they thought they knew how to do this problem, but Alex hushed them by reminding them to work alone first. While students were working on the problem alone, as was the case during every observation thus far, Alex perused the classroom examining student work, asking students questions such as “What are you doing here?”, “Why did you multiply by zero?", etc. As expected, Alex’s use of inquiry with a focus on student thinking appeared routine for his students and him. Alex then asked a student, Johnny, to come to the board and explain how to multiply 30 x 20. Johnny explained that 30x20 would just be double 30x10, so 300 + 300. He reminded the class of multiplying 65x7 by multiplying 60x7 and then adding 5x7 which was the type of problem Alex had indicated he would begin class with. However, the use of the distributive property for multiplying had not been mentioned during the planning session and represented an important departure from the use of the commutative and associative properties which he had yet mention or use.

Alex then posed a new problem, 25x30, and indicated that he was going to show the class two ways to solve it. Some interesting discussions resulted:

[A]: I'm going to call this (pointing at the work on the board) [Johnny]'s method or the breakdown method.

Student 1: I can't do [Johnny]'s method.

[A]: [Student 1], how can you break this down? What's a number that's easy to multiply by? I know you know other ways to do it, but I want to see you do it this way.

Alex (to Student 2): What did you say? Say that out loud.

Student 2: I said I was going to divide to check my answer.

[A]: I asked you to say that out loud because it was a little nugget.

Alex went on to show the class how to break 25 down into 20 plus 5 and multiply 30x20 and then add 5x30. He then stated “that was called the breakdown method. Today is just an exposure day. This is just the first day that we have multiplied two digit numbers”. Alex also showed how to use a 2 by 2 grid to organize these partial products, and he also showed the lattice method. He showed each of these methods using a slightly different example problem. Alex ended class by emphasizing to students that the lesson today was introductory and that they shouldn’t feel bad just because things were hard. Though time restrictions prevented having a reflective interview, Alex briefly commented to the researcher that he felt like he needed to make these procedures more concrete for students. Alex and the researcher discussed using ones, tens, and hundreds blocks to show how an array can demonstrate distribution. Alex indicated that he’d like to see how that worked and arranged for the researcher to observe class the next day while also showing that representation of multiplication.

Classroom observation #5. As promised, Alex began with a tougher version of the introductory problem: “If [Alex] exercises for 4 hours and 50% of the time he's on the treadmill, 25% is stomach workout, and 25% is lifting weights, then how much time does he spend on each activity?” Alex asked students, to ‘teach’ the problem to the class. Student 1 approached the board and wrote then explained that “50% of 4 hours is 2 hours because half of 4 is 2 which means that 25% of 4hours is 1 hour.” Student 2 then stated that “half of a half is a quarter, so 25% of 4 hours is 1 hour.” Alex briefly reviewed multiples of tens by reminding his students that “any number you land on when counting by tens is a multiple of ten.” He then continued the lesson from the previous day:

[A]: Let's review what we did yesterday. How can we break down 34? 30 + 4 (wrote 30 + 4 horizontally on board), and let's just leave the 20 as 20. How do we multiply 30x20 (pointing at the 3 and 2)?

Several students: 6!

[A]: Why do we just do 3x2?

Student 3: Because anything times 0 is 0.

Alex showed the 2x2 grid which he called the “window method” and then stated “and I thought that it might help if I introduced the idea of the array.” Alex then showed the “window method” and explained that if a were in the tens column and b was in the ones column, then the cells would be aa, ab, ba, and bb. Alex then let students work in pairs on 60x34 while he and the researcher walked the room. Alex then asked the researcher, as had been mentioned the previous day, to show the array using tens, ones, and hundreds blocks. The researcher took a position in front of the class along with Alex and showed, while explaining, how to represent 34x20 as 3 tens bars and 4 ones blocks arrayed with 2 tens bars to form 6 hundreds squares and 8 tens bars. Alex showed the corresponding values in the cells of the "windows" method and highlighted the importance of why each product was placed in each box. Alex then explained how 34x20 could be found by "breaking down" 20 into 2x10, so 34x20 = 34x2x10 = 68x10 = 680. Students were then asked to work on 54x30 individually.

Alex once again perused the room asking students what they were doing and why. He worked with some students one on one while having to wake up others. He noted that one student wrote "162 and then just 1620 to get that product" and then summarized by stating "Look at the property of 1. Any number times 1 is that number and any number times zero is zero, so you can just add the zero." He also showed 34x20 using the traditional method with carrying and asked a different student "can you explain why I have to put the 8 over here. It's 2x4 isn't it?" The student responded "NO! It's 4 times twenty!" The lesson concluded with students using the traditional algorithm in groups for 29x40 while Alex and the researcher worked the classroom helping students. Again, no reflective interview could be arranged due to scheduling conflicts, but Alex and the researcher did discuss using base ten blocks and counting by tens beyond 90 to help students understand why you can add a zero when multiplying by ten. These two classroom lessons and the planning session that preceded them provided a unique look into the factors which can impact instructional practices.

Stephanie's Baseline Data

As a student, Stephanie had negative experiences with traditional mathematics teaching:

[Researcher]: Are you teaching math the same way you were taught?

[Stephanie]: No, not at all.

[R]: Why is that?

[S]: When I was coming through school it was problem solving based. It was based on algorithms. Basically, solve the problem using an algorithm.

[S]: I always struggled with math. I always remember it being very difficult and frustrating because it was all problem solving…I don't remember ever having any kind of manipulatives to use or any kind of exploratory…It was all paper pencil with lots of homework. They would show us how to do the problem, how to solve the problem, but not why. Why you solved it that way and why that's the answer.

[R]: So when you teach problem solving, how do you do it? Do you not teach it the same way?

[S]: I basically don't teach it. I give them the problem and tell them I don't care how you solve the problem [giggles about saying 'I don't teach']. I don't care how you get to the answer as long as you get to the answer and you understand why. Manipulatives are out and very easy for them to get to. I do provide them with more than one way to solve by problem.

[R]: How do you do that?

[S]: I show them at least 4 different ways to solve the problem.

[S]: I always give them time to practice it before I say anything. And I encourage them every time: 'Do it the way that works for you. If the algorithm doesn't work for, use the number line. If you don't understand the number line, draw a picture.'

[S]: I stress that I'm not stuck on how you solve the problem as long as you can solve it and you know what you're doing. And then we talk a lot about how we solved the problems. So I will ask somebody, 'did you solve it with a number line' and they'll say "yeah" and they'll guide me one how they solved it and I'll model it on the board and give them some other ideas.

Towards the end of the interview, the researcher gave a brief description of traditional teaching methods. Stephanie confirmed immediately that she had been taught mathematics with a focus on remembering procedures.

[S]: And that's how I was taught. They give you the definitions. What you do. Go do it. If you don't understand how to do, watch me do it. If you still don't understand, good luck to you. "Keep practicing. You'll get it one day."…And they want you to solve it a specific way and show your work a specific way. They don't want you to use pictures. That's where the algorithm comes in because those were SO popular.

Stephanie came to understand these procedures when taking college education courses, but her coursework didn't necessarily prepare her to teach differently.

[S]: The teachers that I had on math [in teacher education courses], on how to teach math, didn't really do a whole lot. It was more like read the book, theories and things like that and not so much strategies and things that you could use in the classroom.

[R]: But you didn't feel like the instruction you got necessarily prepared you as well as you would have wanted to mathematically?

[S]: Yeah, I was prepared, and I was able to come in and teach. I always felt like I could do more and I could do better.

Stephanie began teaching by using the same traditional approach but abandoned these methods when she found that her students were not learning well.

[S]: The first year that I taught it, I did it completely different than I've done the last two years and it was frustrating then…they didn't get it. They don't understand, and it was always a struggle. They were frustrated. I was frustrated. They didn't have the opportunity to share their thoughts and their thinking and say it in their words. They listen to each other more than they listen to me. So if they have the opportunity to speak and share it in their own words, the other kids are going to pay attention to them more than they pay attention to me 'cause I'm just like the Charlie Brown teacher. That's what they hear.

[R]: You started off, if I heard you right, kind of teaching the way you were taught to a degree. But you didn't feel like it was working so well…What made you want try those other ways?

[S]: Because I was so frustrated with it…I felt like the students were not getting what they needed and I felt like I wasn't teaching them what they needed to know.

[R]: How were you able, back then, to recognize that the students weren't learning it the way you wanted them to?

[S]: A lot of stuff that I learned didn't make sense until I was in college…They were showing us reading the book and the thinking behind the strategies and everything and I was like "that makes complete sense; why didn't anybody tell me that when I was in school!"

[R]: Were these your teacher ed courses?

[S]: Yes.

[R]: That's where you learned that you hadn't learned why those procedures worked.

[S]: Yes.

[R]: Is that part of the reason why you were able to recognize that your students didn't understand the procedures?

[S]: Yes. And because I couldn't clearly explain it to them, our end of grade testing scores were not good so we all knew that something was wrong school wide and we were all struggling and it just seemed to get worse and worse and worse.

Stephanie and the other teachers at her school had not observed the same negative trend with other content areas.

Stephanie's school had just adopted *Investigations* in order to support their efforts to reform their mathematics instruction. Stephanie credited the *Investigations* program for helping her evaluate the effectiveness of her instruction.

[R]: How do you know like, during the lesson, 'okay this is working the way it's supposed to'?

[S]: If they can answer the questions. And there are things that you're looking for that the investigation tells you to look for when you're walking around and observing.

[R]: Do you know that because *Investigations* is saying 'look you gotta make sure they do this' or is also some of that what you're looking for anyway?

[S]: Both, yeah, both.

[R]: So the things that *Investigations* is talking about 'hey you should be doing this' that's the stuff you would be looking for anyway?

[S]: Yes. Because *Investigations* isn't EOG [End of Grade Test] specific, but I know what they're going to have to do at the end of the year so I can integrate that with what they're talking about with *Investigations*.

Stephanie also indicated that *Investigations* supported more reform oriented approaches toward instruction. She provided an interesting response when asked about the complaint made by some teachers that the script in *Investigations* takes the art out of teaching.

[S]: My response to that is you don't need to be in teaching. This is not set-up for you to teach them how to do something. It's set-up for them to figure it out on their own in their own way and to share what they've learned with the other students.

[R]: So are you saying that's not teaching?

[S]: It is teaching, but they're teaching themselves and each other. I feel like I'm giving them materials and letting them learn on their own.

[R]: How would you describe your role since you're not teaching in the traditional sense of telling and showing?

[S]: As a mediator and a moderator, and so I would say that as they're explaining how to do something, I'm asking questions. Why did you do that? Why did you choose this strategy and not this strategy? Is there a better way?

Stephanie's school chose to adopt a reform oriented mathematics program in part because her school was a Professional Learning Community (PLC). Data driven decision-making is a critical quality of PLCs, but the teachers at her school acknowledged that they had no data to support the mathematics texts they were using. Stephanie credited the PLC for providing the structure and climate to support appropriate collaboration and community involvement.

[S]: We do all our planning together. We do no planning on our own… All grade levels plan together. That's when we'll be like, man, that didn't work. We need to spend at least another day or two on just this one thing and we'll move our plans to accommodate that.

[S]: Like today, Ms. [Thomas] came in and said 'my kids didn't do so well on this homework' and she brought the homework in and she's like 'look at what they're doing'…We went and got ours and looked at it and it happened across the grade level so we realize we needed to work on that again.

Stephanie indicated that the push from the PLC model to make decisions based on solid data led them to use a pre- and post-test design each quarter in an effort to prepare for the end of grade test. Stephanie also indicated that these assessments helped her identify students who needed assistance:

[S]: I know some kids have more support and more parent assistance at home. The ones who don't, I try to catch them up. When they come in the morning, if they have any questions or really got stumped on their homework, they're supposed to bring it to me and I'll go over it with them.

[S]: They have like 40 minutes in the morning before we start math for them to work on their homework and ask questions and get things done that they didn't have the time to get done at night.

Stephanie also indicated that the PLC model had led to greater interaction between the school and the community. A local church participated in a volunteer program at the school which provided tutoring, free breakfast, and instruction in speaking English for Spanish speaking parents. Finally, the teachers and the principal agreed as a group that teachers would travel as a group to the neighborhoods with low attendance at Parent

Conferences and conduct those conferences in the parents' homes. In general, Stephanie indicated that "We have a lot of community outreach".

Stephanie's Observations

Stephanie and Tracy taught third grade together at the same school. As part of the school's effort to become a PLC, their third grade team always planned as a grade level, so planning and co-planning sessions for Stephanie and Tracy occurred in tandem, though both teachers discussed their planning during pre- and post-interviews as well. The grade level planning time happened to occur immediately after math was taught during the first time block each morning which limited opportunities for post-observation interviews. There were 6 classroom observations and one planning session observation of Stephanie which were more spread out than Alex's and occurred in October, November, January, March, and April. It is also important to note that Alex was working with a very traditional, spiraling math program with which he had some familiarity while Stephanie and Tracy were implementing a new math program on which they had received limited training. Alex was definitely focused on implementing his traditional materials in more reform-oriented ways while Stephanie and Tracy were focused on understanding *Investigations* and implementing those lesson as intended. Stephanie indicated during the baseline interview that both Tracy and she were implementing the first semester of *Investigations* (third grade level) for the first time. Stephanie indicated that her planning revolved around figuring out how to implement the *Investigations* lessons properly. The first, third, and sixth observations reflected this focus. However, Stephanie's implementation of the *Investigations* lesson in the second observation was impacted by several factors. Also, the fourth and fifth observations were not *Investigations* lessons but lessons which had been used by Stephanie previously. The reasons why Stephanie deviated from her stated script in these situations were significant.

Observation #1. This first observation corresponded well with Stephanie's stated lesson plan, though other elements of a typical lesson were revealed. Stephanie was implementing an *Investigations* lesson focused on number sense and place value in which students determined the number of tens in various values and sums. The lesson began with students working individually while Stephanie worked the room. The students had tens bars available to them to help model the problem, and Stephanie was focused exclusively on insuring that students understood the question and did not answer questions about how to do the problem. The students were asked to use their "problem solving cards" to indicate which part of the problem they were working on. Each student had cards which indicated if they were working on: "Read the problem, Re-read the problem (underline key words), Make a plan, Solve the problem, and Look back/check your work." Stephanie told the researcher later the grade level team had used these cards in the past and had found them useful in structuring student thinking while also helping teachers differentiate instruction. It was obvious that students were accustomed to working with the cards, though most students were struggling to just understand the problem. After working on this problem for ten minutes, Stephanie expressed to the class that "it's okay if you didn't finish the problem" and reiterated the importance of using the problem solving cards. Of note, as Stephanie told the researcher later, three students at a time would leave their seats and work on computers in the back of the room. The students were working through an end of grade test preparation program which provided problems similar to those on the end of grade test, assigned more challenging problems based on student responses, and displayed scores to teachers. This program had also been used previously and was also thought to be a good supplemental tool.

A second problem, similar to the first problem, was then written on the board. It asked if Bridget and Kenji would have the same scores if Bridget's score was "317 + 253" and Kenji's was "371+235". Stephanie began by asking students if they felt they needed to add the numbers together to answer the question. She then asked all her students to stand up and move to her left if they felt they needed to add them, to the right if it's not necessary, and stay in the middle if unsure. A few students moved, but several remained in the middle, and some seemed to change their minds based on where some were moving. Stephanie then added the hundreds from each score together in a horizontal method and allowed students to change their minds. Several students were still in the middle. Several students were adding the numbers at their desks with most of the students using the traditional algorithm even though Stephanie had added the hundreds from each without using the traditional algorithm. Stephanie then asked if the number HAD to be added to figure out if they had the same score. Students seemed to understand that it was not required to actually add the numbers. They were then sent back to their seats to re-work the first problem.

Students were told to work in pairs. The ease with which the students worked in pairs made it evident that they were accustomed to doing so. Stephanie had to help some groups focus on the task but then worked the classroom asking students to explain how they were approaching the problem. After ten minutes, Stephanie conducted a whole-class review of the problem through inquiry. Stephanie, without clearly indicating if the correctness of the responses, asked the class questions in the following fashion:

[S]: Wow many are in each stack?

Class (loudly): Ten! Thirty-five!

[S]: What told you how many are in each stack?

Several students mentioned various parts of the story which indicated that there were thirty-five stacks of ten.

[S]: How many in each stack:

Class: Ten

[S]: How many in each single?

Class: One.

[S]: Are you sure?

Class: Yeah!

[S]: Most students counted by tens, so count by tens with me…

Together: ten, twenty, … (not all students kept up at two hundred)

Stephanie then had a student explain how many ones were needed but reiterated "How many stacks of TEN?" Stephanie also noted that grouping single counters by ten made counting easier and that it was very important to read well. She ended the lesson by congratulating the class for their work.

Stephanie had implemented this lesson much as written in *Investigations* but had also added components from previous lessons which the grade level teachers believed effective. The ideals of a PLC include a focus on using methods that seem to work, but Stephanie had also stated a focus on finding whatever works. Students' comfort levels with the problem solving focus, group work, and the use of inquiry made it evident that these practices were common place. One inconsistency however was Stephanie's use of the traditional algorithm for addition with carrying when the focus of the *Investigations* lesson would have warranted a non-traditional algorithm. Discussions with Stephanie during PD would reveal that Stephanie was probably not aware of alternate algorithms. Stephanie also failed to recognize three accurate but non-traditional place value representations of 391 on the pre-Teacher Knowledge Tests (Appendix A) and went on to fail to recognize two of these three representations on the post-test. This triangulation indicated that Stephanie was unable to support this *Investigations* lesson appropriately due to a lack of content knowledge. And though Stephanie correctly recognized one non-traditional place value representation on the post-test, this gap in content knowledge was not completely eliminated despite a distinct the attention it was given during PD and in this math program. In retrospect, it would have been ideal if the researcher had addressed this difficult content knowledge issue during the grade level planning session. Though it would probably have also been necessary to co-plan and observe future lessons to insure teacher understanding.

Observation #2. The second observation took place in mid-November. Stephanie began the lesson with a brief review of telling time using a clock. This portion of the lesson focused on a specific third grade standard and was not part of the *Investigations* lesson. Stephanie used 2-3 minute review problems like this one on telling time to help students transition from one phase of the school day to another. This portion of the lesson was significant because Stephanie had created this portion of the lesson herself rather than relying on a provided script and this type of review of telling time was obviously a habit for students. Stephanie began by having students move the hands on their own pretend, cardboard clocks to reflect different times shown on the board, such 2:10. There was little discussion as Stephanie scanned her students' clocks to insure that each displayed the correct time. Stephanie then asked students to recite the different ways of expressing the time such as "two ten" and "ten passed two". When 2:30 was shown on the board, Stephanie let students discuss whether they would say "thirty passed two" or "half passed two". When her students asked her about the correct way to state 2:30, she asked them "have you ever heard anyone say thirty passed two?" After they indicated that they had not, Stephanie stated that she had not either. However, she did not state whether they were correct or not. Throughout this review, Stephanie utilized inquiry almost exclusively. She did not demonstrate a focus on student thinking by asking students how they had obtained their responses, but it was also obvious that Stephanie believed her students knew this material well and wanted strictly to review briefly. It is important to note that this introductory activity, created by Stephanie, reflected her professed belief in the effectiveness of inquiry. After this introductory activity, Stephanie implemented the *Investigations* lesson.

In this lesson, students were first asked to count out 40 connect cubes and were then read a lengthy description of the differences between two snakes: "Redbelly & Eastern Ribbon." The Eastern Ribbon snake averaged 21inches long while the Redbelly average 9 inches. Students were asked "How much longer is the Eastern Ribbon snake than the Redbelly?" and were given time to work together to determine their answer. Some students were unsure of the question and Stephanie explained "you have to figure out the difference between them". About two thirds of the class immediately, and for the most part correctly, executed the traditional subtraction algorithm. While Stephanie perused the work of the different groups, she noticed the reliance on the traditional algorithm and reminded the class that “the reason you might not want to go straight to the algorithm is because it might not always work.” Some of these groups then started solving it using a number line and/or the cubes in addition to, or instead of, using the algorithm. The remainder of the class relied on the cubes or the number line to solve the problem.

After noting that each group appeared to have the correct answer, Stephanie asked two students to show how they solved it. One student solved it using the number line and one relied on the cubes. The student using the cubes simply broke off the portion of cubes that were different between the two ‘snakes’ and then counted the cubes. Stephanie did not ask questions of this student. Stephanie asked the student who used the number line to explain why he started counting at 9. The student was unable to provide a clear response, so Stephanie opened the question to the class. The class as a whole struggled to articulate why they would start at 9, and rather than tell them why, Stephanie tried to ask just the right questions to facilitate student thinking. Stephanie noted the importance of not subtracting 9 from 21 but rather comparing the lengths just like “the difference between two books.” Stephanie also highlighted the approach of a student who counted two from 9 to 11 and then counted by ten from 11 to 21 to count 12. Stephanie tried to make sure that students recognized the intelligence behind this approach. Stephanie also let a student show the traditional algorithm and explained that regrouping was "breaking up a ten into ten ones." Time was up at this point in the lesson, and Stephanie began transitioning her class to their next location.

Stephanie utilized inquiry quite effectively during the lesson introduction and throughout portions of the *Investigations* lesson. However, during other portions of the lesson, Stephanie appeared to lack a clear vision of the lesson goals. Regrettably, due to scheduling conflicts, no post-observation interview occurred which would have provided stronger data. But since this was the first time Stephanie had taught this particular *Investigations* lesson, she probably did not anticipate the need to address students' understanding, or lack of understanding, of the traditional algorithm for subtraction. She probably would have been able to prepare questions that forced students to deconstruct the algorithm had she known that so many students would rely on the algorithm. Also, had she been more familiar with this lesson of the lesson goals, she would have known to ask students if counting down from 21 to 9 would work. Finally, it would also have been preferable to have ten unit rods along with unit cubes prepared to model the snakes' lengths instead of having kids count out 40 cubes. This would have made it easier for kids to quickly model the situation and would also have made the borrowing concept evident. Also, a student might have recognized that using the lengths 10 and 22 would be much easier than counting out the five unit cubes required for 9 and 21 and would also make it easier to determine the difference. The contrast between Stephanie's facility when teaching through inquiry with the clocks and difficulties mentioned above highlight the roles played by her understanding of the lesson goals, her experience teaching these lessons, students' background knowledge, and the impact of the curricular materials provided to students. When all four of these factors were in place, Stephanie's use of inquiry was smooth and well directed. When these four factors varied during the *Investigations* lesson, Stephanie had distinct difficulties facilitating her students' learning. Lastly, the impact that could have resulted from pre- and post-observation interviews further highlights the potential benefits of designing professional development based on the *CI Model*.

Observation of team planning session. In early December, the researcher observed a third grade team planning session after observing Tracy. This observation is accounted here because a topic that was discussed during that planning session had a direct impact on Stephanie's planning and instruction. The team indicated that the goal of this meeting was to create a pre-assessment and plan for an upcoming unit on measurement. Stephanie began this discussion by indicating that the team should skip the *Investigations* unit which dealt with area they should skip area "because they need to know multiplication to do area and it's not included in the standard course of study." This comment was significant as it revealed an underlying belief that students needed to learn to multiply before they could learn about area instead of learning about the concept of multiplication by studying area is intended in *Investigations*. As the meeting progressed, the researcher began to recognize that when these teachers said multiplication, they actually meant the traditional algorithm rather than repeated addition. In the moment, the researcher was swayed by Stephanie's argument that area was not on the end of grade test. Also, at the time, the researcher was not familiar with this particular *Investigations* unit and was unsure if the unit in fact was designed to introduce the concept of multiplication using area. The third grade team was also swayed by Stephanie's argument and agreed to plan the following unit on US and metric measurement. At this point, a third grade teacher who was not a participant in this study mentioned a teaching approach which would ultimately play an important role in Stephanie's practices. The teacher indicated that she knew a good way to teach students how to remember when to multiply and when to divide. This teacher showed a dance in which she spread her arms to show going from a "little" unit of measure to a "bigger" one. Her spread arms then tilted to represent the division symbol while she sang "to go from little to big, divide". And then to show going from big to little, she reversed the process with her hands and then crossed her arms to represent the multiplication symbol: "and from big to little, multiply". The researchers, along with the other team members, smiled and laughed a little at the display. However, the researcher had no idea at the time that the teachers, Stephanie specifically, would actually use this pneumonic as a teaching tool. Observation #5 accounts this lesson.

After agreeing on skipping the area unit, the team agreed to use a pre-assessment on this unit. Stephanie mentioned using one last year, and the team agreed on using that assessment. Again, the researcher was unaware of the significance at the time of Stephanie's perception that she taught the measurement unit well the previous year. After agreeing to use the previous year's pre-assessment, the team turned their focus on planning. Three of the four team members had been trained regarding the use of the 5 E's Lesson Planning format during formal professional development over the summer. The 5 E's are Engage, Explore, Explain, Elaborate, and Evaluate, in that order. However, the team only discussed that they would use their "10 minute math" activities as introductory activities to "engage" their students. The team did not indicate any need to plan for the remaining 4 E's. Also of significance was that the team's planning dealt strictly with pacing: what to do and when to do it during each class period and each week. There was no attempt made to discuss instructional practices. However, there was also no time to do so as the planning session ended before the teachers had 'planned' more than the next week's activities. These teachers only had this one planning session each day and had to plan every other content area in addition to mathematics. It simply would not have been feasible to discuss instructional issues along with pacing.

Observation #3. The third observation occurred in late January and the *Investigations* lesson focused on division. Stephanie presented the problem “If frogs have 4 legs and there are 16 legs in a pond, then how many frogs are in the pond?” and then asked students to first visualize the pond and frogs. She then gave her students three minutes to do whatever they need to get the answer working alone. One student indicated that she didn’t know how to write the equation, but Stephanie told the class to just focus on showing how they got their answer. She then told students they could work together for four minutes, and the kids immediately leapt into group discussions. Most students had drawn different types of pictures representing four groups of four and the discussion revolved around students explaining how their pictures represented the frogs. After just two minutes, Stephanie announced that she had heard “lots of good stuff” and now wanted to discuss their solutions. From the board at the front of the classroom, Stephanie asked a student “what would you do to draw a picture?” The student said she would draw four circles but couldn’t explain why. Stephanie asked if she drew four circles because she knew that four times four was sixteen. The student responded yes. Another student described drawing four groups of four tally marks. Stephanie asked “Why did you put your tally marks in groups of 4? Don't you usually put tally marks into groups of 5? What about the problem told you you would need to put your tally marks into groups of 4?” Several students muttered that each frog had four legs. Stephanie replied “so each group of 4 tally marks represents a frog, right?” Another student showed Stephanie that he had made eight groups of two. Stephanie noted that another student had done the problem that way. Stephanie also told the class that they could use the numbers 4, 8, 12, and 16 instead of tally marks or circles if they wanted. Then Stephanie told the students put away their math journals on which they were recording their thoughts.

For the remainder of the class, Stephanie had students working along on a worksheet with four division problems on it. While students worked the problems on the worksheet, they also used their problem solving cards to show which part of the problem solving process they were on (Read the problem, Re-read the problem, Make a Plan, Solve the problem, Check your work). While students worked the problems on the worksheet, Stephanie walked the room and helped students with a clear focus on inquiry. When students finished working the problems on the sheet, Stephanie had a few more problems prepared which were more difficult than those posed on the worksheet. Not all students remained on task, and drawing pictures to represent division actually distracted some students who were able to solve the problems fairly easily in their head. To test their comfort with solving challenging problems, the researcher posed a problem to a couple of students involving numbers which did not divide evenly. The students recognized this difficulty but seemed undisturbed by having to try and figure it out. Time ran out without any closure on this lesson.

This lesson clearly revealed students' comfort level with working in groups, explaining their thinking, sharing their ideas with each, and using multiple approaches. It was particularly striking that students were obviously comfortable with Stephanie moving forward toward individual practice without telling the class which approach was "the right way" to do the problem. Stephanie's professed tendency to view mathematics, mathematics teaching, and mathematics learning as predominantly an individual process of discovery for students was prevalent throughout this lesson. Stephanie's professed preference for using inquiry was also evident as was students' comfort level with its use. Stephanie also indicated a definitive reliance on student understanding to determine how well the lesson was progressing. In general, this lesson was conducted as would be expected based on Stephanie's professed beliefs.

Observation #4. The fourth observation occurred the following week in an effort to catch a cycle of related lessons. This lesson also began with a brief problem on telling time much like the second lesson observed.

[S]: What time is it?

Class: 7:40

[S]: If I'm going to leave my house in 35 minutes, when am I planning on leaving?

The students were still trying to get settled down (recall that Stephanie and Tracy teach math first thing in the morning). Stephanie provided several minutes for students to work the problem, but she was also busy setting up for the day herself. The researcher walked the room and noticed that several students were having difficulty solving the problem using a number line. Stephanie then had her students put their answers on cards which they held up. The researcher did note that several students just wrote down the answers that their neighbors were writing. Stephanie walked the students through counting by five's on the clock and also on a number line where she explained that they needed to count "eight o'clock" instead of 7:60. Stephanie also mentioned to the class that the clock would be up on the wall just like it was for this lesson during the end of grade test and that they should use it. Following this 15 minute clock problem, Stephanie began the designated math lesson for that day.

Stephanie announced that they would be working on “missing factors” today. She began by having a student go to the board to show a 5X4 array. She then asked the class as a group to answer the questions “What is five times four? What is four times five? What is twenty divided by five? What is twenty divided by four?” As a group, the responses varied a bit with a majority of students not responding right away. There were a few students who knew these answers, but there were also several students who were not responding immediately. Stephanie appeared to focus on those students who were answering the questions correctly. She was also clearly not checking for individual student understanding. Stephanie then asked the class to examine a board at the back of the room which had obviously been placed there for this lesson. The board consisted of a square grid with each square containing two numbers. One number was written in large font, and the number written in smaller font was a factor of the other. Stephanie explained that for each square, students were supposed to write up the four fact families based on the two numbers. She used the example of 44 and 4, and showed that students were supposed to write 4X11=44, 11X4=44, 44/11=4, and 44/411. Students were then told to work on their factors cards alone for the remainder of class.

Before this lesson began, Stephanie apologized to the researcher because she was going to have to leave after she got the class started to attend a meeting. Stephanie was not pleased about having to leave class to attend the meeting. Stephanie was forced to alter her lesson plans for that day to accommodate the meeting, and left the class after asking them to work alone on the factor board. Stephanie had altered the original instructions for the factor board which led to some confusion as some of the squares contained the two factors and required students to figure out the product. Stephanie's assistant, with the researcher's help, had to explain to students what to do with those squares. Another problem was that there was a multiplication table posted on the wall at the back of the room. A number of students relied heavily on this table to figure out what to write down on their factor cards instead of working through the multiplication and division on their own. Some students even completed the factor cards by working through them in the order in which the multiplication table was organized. Moreover, several students explained to the researcher that they would have unable to complete the factor cards without the multiplication table because they were unable to count by 7's or 8's for example. There were also several students who were not behaving well with Stephanie gone. The assistant teacher appeared a bit overwhelmed and was appreciated of the aid provided by the researcher. At one point during the lesson, Tracy's assistant (all of the third grade teachers attended the meeting) walked into the room to ask about the instruction for the factor board.

This lesson on missing factors appeared markedly different from the previous three lessons. This lesson was not from *Investigations*, and the use of inquiry, problem-posing, and the focus on student thinking which were prevalent previously were non-existent during this lesson. Instead of working in groups, students were working alone, and instead of working in depth on a few problems, students were posed with over 20 problems on that factors board. Due to the meeting Stephanie attended, no post-observation interviewed occurred which would have provided valuable information. The researcher again recognized the need to observe the planning stage and reflection stage in addition to conducting a classroom observation to gain a complete picture of the teacher and this lesson. But it certainly appeared that having to leave the classroom for the majority of the lesson had a tremendous impact on Stephanie's planning and implementation.

Observation #5. The fifth observation occurred in late February. This lesson was one of several lessons measurement, units of measurements, and converting within customary and metric systems. Last year, it had appeared helpful for students to develop a structure for learning these two systems. This structure included converting, giving examples, and listing tools for measuring. The students had been exposed to customary and metric units for length, weight, and capacity but were struggling with converting within each system. Because these topics seemed challenging for students and perhaps for teachers as well, the four third grade classes were re-grouped by ability into two classes. The two lead third grade teachers, one of whom was Stephanie, were asked to teach this lesson on capacity and conversion while the two teachers new to third grade, one of whom was Tracy, were asked to play more of an assisting role. Stephanie led the lesson with the group of higher performing students which included her class. Of note, partway through this lesson, the other third grade teacher expressed that she was impressed with Stephanie's instruction and would not have been comfortable teaching this lesson.

Stephanie began by reviewing that "milli" meant "mini" in the metric system, and she also reviewed the customary and metric units for length (inches, feet, yards, and meters), weight/mass (pounds and grams), and capacity (pints, gallons, and liters). She then asked students to list the tools they might use to measure capacity in milliliters.

Students responded with test tube, dropper, measuring cup, etc. and responded with soda bottles and canned food when asked for examples of measuring in liters. This led well into a discussion, for which Stephanie was well prepared, of when capacity was used. Stephanie brought out a bag of lollipops and asked students “why did they measure lollipops by weight?” Students were encouraged to work in groups and immediately broke into discussion. The researcher focused on one group to observe who noted that the lollipops were measured by weight because they were solids and not liquids. The group later noted that solids occupy space differently than liquids. Curious, the researcher asked the group if the empty 500mL water bottle he had held anything. The group members all agreed that the bottle no longer held 500mL which clearly revealed students’ difficulty differentiating capacity from weight. The researcher noted that Stephanie did not use the term volume when discussing capacity and that she used the terms area and space interchangeably. Stephanie then wrote on the board “1L = 1000mL” and introduced a conversion problem for the groups to work on.

As Stephanie began stating the problem, she told students that “we've actually done this.” She then listed different distances, some measured in feet and some measured in yards, that five children had thrown a ball. The groups quickly broke into discussion, and the researcher again focused his attention on one group while Stephanie, the second third grade teacher, and the assistant moved through the classroom helping different groups. The group observed by the researcher struggled to stay on task and. At one point, they believed they were done with the problem, but when asked, members of the group gave different responses. However, the difficulty for the group clearly centered on how many feet six yards would be. Before the group was able to arrive at a consensus, Stephanie called the students back to discuss how to solve to the problem. At this point, Stephanie began teaching in a fashion which surprised the researcher quite a bit. Not only did Stephanie tell the students how they should solve this type of problem, but she showed them a cute way to memorize the approach, and stated that this trick would work for all three types of conversion problems. To convey this approach to students, Stephanie stood in front of the class and, as she stated "to go from little to big, divide!" she moved her hands from close together to farther apart and then tilted them to represent the fraction bar. Then of course she stated "and to go from big to little, multiply!" during which she took her spread arms, closed them, and crossed her forearms in front of her face to resemble the multiplication symbol. Notably, she did not explain why students should multiply or divide. She finished the lesson by having students convert to feet and reminding them to always make sure they answer the question.

This particular lesson presented a unique situation. The content was obviously quite demanding for these teachers. Stephanie missed six of the seven questions on the pre- and post-test versions of Content Knowledge Test that dealt with linear equations and formulae. The first portion of this lesson aligned well with Stephanie's professed beliefs and practices, but the second portion of the lesson was almost the antithesis of her beliefs. The researcher was able to speak with Stephanie briefly after this lesson and indicated his concern regarding this type of instruction. Stephanie readily acknowledged that students "might not REALLY understand" conversion from an instructional strategy based on memorizing a procedure. However, the grade level chose this approach because it was deemed successful based on the test scores of the students with whom it was used the previous year. This entire unit was designed with a clear focus on the end of grade test, but the third grade teachers were behind their schedule for the year and indicated a need to get back on pace. Adding to this difficulty was the lack of focus on this specific set of skills in the *Investigations* program which meant that the teachers had to develop this unit on their own. Stephanie's use of instructional strategies that seemed opposed to her beliefs appeared to be impacted by content knowledge, perceived success on the previous end of grade test, time constraints, the school's structure by grade level, and the available curricular resources.

Observation #6 and planning session. The sixth and final classroom observation occurred in late April which was two weeks before the review for the end of grade test would begin. This observation also coincided with a professional development planning session. One of the lead researchers had scheduled a planning session with the third grade team which began immediately after they taught math that day. The observation will be discussed followed by a summary of the key components of the professional development planning session.

The focus of this lesson was evident from the start. Stephanie asked her students "what have we been working on?", and they quickly responded "geometry!" Stephanie then reviewed the characteristics of polyhedrons before explaining the "game" that they were going to play that day. The game was called name that shape and came directly from *Investigations* though Stephanie had not taught this lesson previously. The rules in this game forced students to communicate and think critically about the different characteristics of the three-dimensional shapes they were studying (rectangular prisms, cubes, cylinders, triangular pyramids, cones, and spheres). The students were divided into four groups of four to five students and had to try and guess the shape that Stephanie had hidden. The teams took turns asking yes or no questions only. Students were not allowed to ask if the shape was a particular shape, nor were they allowed to point or ask if the shape looked like some other shape. Stephanie then reviewed the shape, their names, and some terminology. Some students were not engaged during this review, but when the game began, every student seemed quite engaged in working with their group to discuss which questions to ask. Below is the transcription of the second round as there were some problems with the first round:

Group 1: Does it have points?

[S]: Yes.

Group 2: Does it have a triangle?

[S]: No.

Group 3: Does it have any faces?

[S]: Yes.

Group 4: Does it have points?

[S]: Yes. Okay, discuss with your group.

Stephanie checked on a couple of the groups, and reminded one group that if they guessed, then they would be out of that round. After some heated discussions amongst the groups, the groups all agreed that they were not ready to guess yet, so Stephanie allowed them to ask more questions.

Group 1: Does it have eight points?

[S]: No. hm …(counting in her head) Oops (giggles). Yes.

Group 2: Does it have two faces? (teammaters whispered “no” when this question was asked)

[S]: No.

Group 3: Does it have six faces?

[S]: Yes.

Group 4: Does it have square faces?

[S]: No. Well, be more specific with your question? Okay, I'm going to say yes and no. Talk to your group if you're ready to guess!

With obvious enthusiasm, the groups jumped into discussion. Each group wrote down their responses on a sheet of paper which they then gave to Stephanie. She collected all the sheets, and then read each group's response. Three groups said cube while one group said prism. Stephanie then clarified that the rectangular prism had two square faces. She also differentiated between edges and points which she stated were actually called vertices and vertex for singular. Stephanie told them that these were the last terms they had needed to learn. The students then began round three which all the groups answered correctly. The hidden shape was a cylinder. Stephanie finished this lesson by reviewing faces and edges "you're good on those" and vertices "which you need some work on". There was time for a brief post-observation interview after this lesson. Stephanie indicated that this lesson had come straight from *Investigations* but that she had not taught it last year when the third grade piloted the program. She was really pleased with how well the lesson had gone because her students had asked such good questions.

PD planning session. A primary focus of this planning session was to help prepare these third grade teachers for the end of grade test review sessions that would start in two weeks. The lead researcher directing the planning session reviewed some data that had been collected from the third grade students who used a computer-based program to prepare for the end of grade test. The researcher indicated that their students had trouble converting real-life contexts into equations and answers. Their students also had trouble with proportions and situations when they needed to multiply. The researcher indicated that the teachers could work with students on converting to real life situations and proportions simultaneously. The researcher discussed the benefits of always trying to build algebra into the concepts they study. A teacher who was not a participant in this study commented that they should let the indicators from the computer-based program guide their planning for the review sessions. Based on the lead researcher's recommendation, they decided to work on properties before covering order of operations. The researcher emphasized the need to cover properties without simply having students memorize them: "don't do properties in a dry way: any number times 1 is itself". The teachers then discussed different ways to cover properties that would keep students interested while also helping them gain an understanding of the properties. Stephanie mentioned that giving each student a role, like a parenthesis or multiplication or number, and letting them maneuver themselves physically to create equivalent expressions can achieve both goals. The lead researcher mentioned that the students would need to understand how to apply the associative and commutative properties. For example, they would need to know that 4*2*5 becomes 4*5*2 using the commutative property while doing 2*5 first can be done by using associative property. It was apparent that several of the teachers were not aware that students would be asked to apply the properties in this way. One teacher noted that this discussion had made her think differently about teaching these lessons. During this planning session, the teachers also discussed the geometry lesson they had all just taught. They were all very pleased and impressed with the level of thinking revealed by the questions their students asked during the geometry lesson. The teachers agreed that the second grade teachers had prepared these students well.

Stephanie's End of Study Data

In March, Stephanie was observed teaching a lesson on measurement during which she appeared to focus on teaching her students a cute pneumonic for converting between common units. This lesson seemed drastically different than the other lessons observed and in distinct contrast to her professed beliefs. During the end of study, Stephanie was asked about that lesson's effectiveness. She revealed that the pre- and post-test data had indicated little growth in the area of measurement. She readily acknowledged that those lessons for that unit had not been effective. She also revealed several different factors that she felt impacted her teaching of that unit.

[R]: I also wanted to ask you about a specific lesson. I think we talked about it briefly. It was one that I recorded. I hate doing this to you.

[S]: That's all right.

[R]: The one where you stood up and (mimics Stephanie's arm movements during the lesson) 'division'.

[S]: (laughing) Oh, yeah.

[R]: Do you remember that? The measurement one?

[S]: Yeah.

[R]: That one was not from Investigations, right?

[S]: Right.

[R]: And if I remember correctly, that was one you had used previously?

[S]: Hmm, hmm,

[R]: And how did you feel like it went when you used it this year?...Did that lesson go the way you wanted it to this year?

[S]: I think that whole unit didn't go (laughing) the way I wanted it to. We haven't figured out, really, a good way to teach that. I had used it last year and it seemed to work better last year than it did this year.

[S]: We just have no guidelines, no materials, and no really anything to pull from so we had to come up with everything on our own.

[R]: And so you felt like it worked okay last year and that's kind of why you did it this year and also because you didn't really have anything better? Is that accurate?

[S]: Hmm, hmm. I think that it should not have been taught with that many students in there.

[R]: Do you think that's why it didn't work as well?

[S]: No. I don't think it would have worked really any better. I think that with two assistance and two teachers in there when I was really the only one who had any kind of background knowledge on it and conceptual understanding of what I was trying to do that that hurt some of it too.

[S]: When I did it the year before, I did it with [Sarah] and we both knew. So that kind of hurt. Some of the kids had questions and [the other teacher] wasn't really sure so…

[S]: I think that this [coming] year, since we'll be working together again, that we'll be able to come up with something hopefully better. I think you learn most from your mistakes.

[R]: How are you hoping to change that lesson?

[S]: I'd like to do something more investigative. But then again, we just didn't have the time to get them to measure things and discover what they're figuring out between converting two things…

[S]: We just were not allowed the time. That goes back to spending eight weeks teaching addition and subtraction because we lost four weeks of instruction that we needed to teach measurement.

[R]: And you in particular felt like you could have skipped a whole bunch of that.

[S]: Hmm, hmm.

[R]: So how come you aren't able to utilize the time in whatever way you'd like?

[S]: Part of the reason is [the school] is a Reading First School which is a reading grant. So we have to spend an amount of time uninterrupted in reading which is a 90 minute block, and then we have to spend a certain amount of time every day in a reading intervention and that is the hugest block of time. What's left over...our next largest block of time is math and then the only thing that's left over we have to combine writing, social studies, science, and anything else that goes in there.

[R]: So how come you just didn't do the unit a week longer if you were restricted on times you could do it?

[S]: Because we were trying to get everything in before they took their end of grade test.

[R]: So you were restricted the amount of time during the day and the amount of time you had left in that year?

[S]: Yes.

[R]: Would you say that had a significant impact on that unit?

[S]: Yes.

[R]: Would you also say that you would have loved to have planned that unit differently beforehand but you lacked time to plan it differently and resources to do it differently.

[S]: Yes, sir…. That's my big wish list.

[R]: How did they do on measurement on the end of grade test?

[S]: I don't know.

[R]: So what makes you think the lesson didn't go as well?

[S]: When they took their pre- and post-test, the post-test did not show growth hardly at all with any of the students, because that was a skill that was completely new to them.

[R]: So in that situation the habit you guys have of being data driven, the data made it pretty clear that they hadn't grown as much as you would have liked or just hadn't grown much at all?

[S]: In my opinion, they didn't grow much at all. I think that the one thing that they really got kind of cheated on was the measurement.

Tracy's Baseline Data

The conversation below, which resulted from a question regarding reflection, illustrated this motivation. This portion of the interview also demonstrates the impact of her beliefs towards mathematics and the ways in which Tracy reflected on her teaching to gauge lesson effectiveness.

[R]: You said that after a lesson, you take some time to decide if the lesson went well.

[T]: Yes.

[R]: When does that usually occur?

[T]: Usually after the students…Well, I can't say that. [pause] There are some days that if the students are working on …

[R]: ‘cause you obviously check on it during the lesson.

[T]: Yes.

[T]: There are some days, if the students begin working on an activity and I've completed the lesson, I'll start thinking, reflecting about what happened, what were the responses, and if I question it, sometimes at that point I'll just say "okay guys, let's stop for just a moment and let's go back" and we'll go back.

[T]: And there are days that I do it after they leave. If I'm looking over work or looking through their math notebooks. I don't know. Sometimes I have to write notes down for myself and then the next morning when they come back in I'll say "guys, lets go back to this for just a few minutes." I try to do that without confusing them.

[R]: Now is that focus on your teaching where you want to know how they're approaching it, you want to know what they're thinking about. That's, I guess ,the way you were taught?

[T]: Not really.

[R]: No?

[T]: No. When I was in school, we had to do it one way that was the teacher's way. But I felt, I feel like I missed out on a lot. I was not…I was a slow learner. I had to really see it and do it and sometimes I mean it just took somebody sitting there with me.

[T]: I feel like I'm deficient in a lot of areas especially like with math…I was not a great student. And I just remember it always having to be one way. So I'm trying to let them be a little more creative. Like I said, if they can prove to me that they did it, you know, in a method that it will be right each time. If they can show me how they did it and prove it to me, I'm good with that. And I don't know if that's necessarily the right thing do, but I feel like …they continue to think and be creative and know that it's important.

[R]: So you've always liked math?

[T]: Yes.

[R]: And you're always pretty good at it?

[T]: I think so, but I feel like there were things I had to learn on my own.

[R]: And you're in accounting?

[T]: [laughs] Yeah, I did accounting work…

[R]: But you think that you were a slow learner at math?

[T]: Yes. Yep.

[R]: You see why those things seem to be at odds to me?

The researcher went on to explain that teacher's experiences as students frequently impact their teaching. Tracy then explained that she really liked teaching math even though "math is the scariest" for her because the concepts she's teaching seem different than what she learned.

[T]: Right now, I'm not feeling like…I'm not feeling totally grounded yet. I guess because this is my first year, but it is my favorite…. I like math. I like teaching math now.

[R]: Even though the math you teach now is different than the math you took?

[T]: Yeah, yeah.

[R]: So which one's math? The one you took or the one you teach?

[T]: Which one's the math?

[R]: Which one's the math because it sounds like you're describing two very different things.

[T]: (with conviction) The one that I teach. That really is diving into numbers more…It's utilizing numbers in various ways. Where as before it was nuh-uh (shakes her head).

[R]: And do you feel like you're not so good at it because it wasn't the way you were taught? And you're having to learn …

Tracy interrupts: Unfamiliar. Yeah. Being unfamiliar with it.

[T]: And when I say new, (muffled-starts again) If I reflect on a lesson and I feel like it didn't go well, I can get with my cohorts here and they can tell me what they did and I can "okay, let me just try that. I'll do that". But because we're in *Investigations*, and we all talk about it daily I feel like I try to be on the same page with everyone and if I have to tweak something a little bit, then I'll do that.

Tracy discussed the uses of the thousand charts the students were making before indicating why she didn't feel the lesson went well.

[T]: And it just did not go like I had planned at all today.

[R]: And was that really strictly due to a lack of time?

[T]: Yes.

[R]: Because the assessment took longer than you thought it would?

[T]: Yes, if I would have had maybe another 15 minutes. Explaining to my students is…half of them can truly listen and watch me do it and then the other half, they have to be doing it. And I had 4 or 5 students who were out this morning with being pulled out and it just was not in synch at all.

Later in the interview, the researcher followed up on the discussion above and asked Tracy to discuss a lesson which did go well. The lesson Tracy chose to describe involved students working in small groups to make $2 using various combinations of coins.

[R]: So you had a lesson on money that you felt went well.

[T]: Yes. [Tracy summarized the lesson]

[T]: They did very well in their small groups. I think they did get the lesson though. I do feel that they understood it well enough.

[R]: And what was the goal in the lesson? What were you hoping they would get out of it?

[T]: Just the understanding of what it would take if they… [to herself] I'm trying to think how to explain it… if they were given different coins to use. If they were given $2 worth of quarters and ten dimes or what they could use to make a certain amount of money...They're various ways to do that.

[T]: I don't know. I just think that even that simple concept for some reason to me was really important for them to get. It's not just one way. I want them to think outside the box.

[R]: So if I understand correctly, it's in essence a number sense, problem solving game.

[T]: Yes.

[R]: How was it that you came about to determine that you felt it was successful?

[T]: A lot of observation. I would go to each group and get them to explain to me exactly what they were doing…If they say "well, I used this", I love to ask "well, why?", or "tell me how you did that". I would basically do an interview with each of them when I would go to their small groups. I did not give a formal written assessment at that point for that.

[R]: Would you say that's a typical technique during the lesson of seeing how it's going?

[T]: For the most part. They use their notebooks-they have a math notebook they use quite often, basically every day, and I like to go back through and see how they will work out a problem. We do have worksheets, but I like for them to really tell me and show me. I like the worksheets. They can draw things on there and show me how they got it and they can use pictures to give me their answers, but I really like for them to tell me and then show me with the physical in their hand.

The follow-up discussion shown above helped reveal Tracy's focus on student thinking and her claim that she would try to assess students' thinking during class through inquiry and small group discussion. However, in this excerpt, Tracy appeared to lack awareness of the overarching goal of developing number sense and focused on the problem-solving benefits of the 'game'.

Tracy also indicated the role played by her previous teaching experiences:

[Tracy]: I needed to strengthen my math skills with teaching math and just personally needed to strengthen my math skills. I did a little research on [the professional development program] and I just thought that would be the best way to do it.

[Researcher]: Why do you say that you needed to work on your math?

[T]: I've always loved math. I've been really good with numbers, but ... problem solving has been, I guess, a struggle for me. I came to [the current school] from teaching first grade for five years, and it was direct instruction and so it was so scripted and I had really gotten out of higher order thinking.

[T]: I always had really high classes …but it was different. When I came to fourth grade, I had to really study my plans and really re-learn fractions and I was always asking questions and it kind of made me feel very, I guess, insecure about my math skills. I felt like I was doing a lot of studying and prepping for the lesson.

[R]: Now you said that you always were good at math and always liked math…

[T]: Yes, but for some reason teaching it to students: different.

[R]: You said you worked for five years in first grade but that it was very…you used a word and I don't want to put a different one in your mouth. What did you say about it?

[T]: Yes, I always had the higher students, so it was really interesting, it was direct instruction….so it was right there in the book but all I had to do was read and teach but the creative side of that was never there because it was always just given to me and I had to follow that, those guidelines.

[T]: But when I was able to get here, my first year of teaching fourth, I mean it was every night I had to truly take that book home with me and solve the problems and try to figure out a way to explain it to the students so they would understand it...the translation of that is hard for me...

[T]: I thought, well maybe if I do the [PD program], maybe I would learn different strategies, become more comfortable, really dive into it more. That's just really important to be able, not only for me to have those skills, but to be able to teach those skills. I felt that I had them. I thought I was a great math student…but boy, teaching it to students is way different.

[T]: *Investigations* is so hands on... it meets the needs of all students I feel because it's easy for them to do it, to talk about it with their partner. The other way I just felt like they were just getting out of the book and that was hard for me because then I had to develop different ways of meeting each student.

[R]: Some teachers have complained that *Investigations* is really scripted and they really don't like that…and it sounds like you're saying you were being scripted in first grade with direct instruction so I'm trying to figure out …

[T]: The difference? It's more hands on…They're talking it out and working more with solving the problem with partners. When I taught it in first grade it was they're sitting at their individual desk, they're not talking, they have no communication with each other, there's no working with hands on anything. It was just pencil in hand, paper, and that's it.

[R]: I'm going to put words into your mouth just because I think you're wanting to use them…What it sounds like you're describing is not just direct instruction in first grade but very teacher centered direct instruction.

[T]: Yes, totally, yes.

Tracy's Observations

During the baseline interview, Tracy detailed her motivation and commitment to teaching through the use of instructional practices that were drastically different than those she had experienced as a student. She also indicated a commitment to observing student thinking and utilizing *Investigations* as intended. However, she also indicated that she measured lesson effectiveness in terms of the lesson going as planned. And she never detailed an ideal lesson script which aligned with the non-committal nature of her views toward mathematics and mathematics teaching and learning. From the baseline data, the researcher anticipated that Tracy, lacking a clear view toward teaching, would struggle with decision-making and present inconsistent practices. The observations detailed below corroborate this hypothesis with Tracy's practices clearly impacted by motivation, formal professional development, the *Investigations* program, but also by her experience, knowledge, and the classroom and school climate.

Observation #1. This first observation occurred in late October around the same time as the first observations of the other participants. Tracy spent the first several minutes taking attendance and organizing things to prepare for the lesson. She first worked with her students on preparing for a long term project they were working on in which the class was going to collect 1,000 things. She let the class chose whether they would collect things in bags or jars and asked the class as a whole how many they would need. The students chose jars and indicated that they would need ten of them. It was apparent that they had been discussed this project previously, and Tracy reiterated that they would be "creating charts to map their progress" toward collecting 1,000 things over the next several weeks. The students had become restless, so Tracy moved into the *Investigations* lesson.

Tracy wrote the equation “90+10+147=160+40+40+7” on the board and had the students read it together with her. Tracy did not write the question on the board. She then gave her students the following set of instructions:

[T]: Excellent! Okay, so we, we, you guys just read an expression. Um, write this expression out and then tell me what it equals. (pause) Work it out. Write this expression out, and then work it out. Show me your work. I want to walk around and see your work. I’m going to … (student interrupts) If you need to break that down...One thing I’m going to suggest is that you look at what can total one hundred and that would help you solve this equation.

Students were then permitted to work independently while Tracy and the assistant teacher moved throughout the room. The researcher took this opportunity to address Tracy’s incorrect use of terminology by explaining that the equation on the board was stating that the two expressions were equal. Tracy focused on providing guidance to students and asking question rather than answering questions the students had. Most of the students were using graph paper to count the two sums. Several students also began to discuss the problem with each other while several others seemed distracted with one female student reading a book. After this individual work time which became group work time for several students, Tracy obtained the class’s attention from the front of the room and asked students to explain how they approached the problem. The first student she called on approached the board and simplified the left expression using the traditional algorithm for finding the sum of three or more numbers. While this student was showing their work

Tracy summarized that the student “solved the left side of the equation”. Tracy asked a second student, the student who was reading a book, to “solve” the right side of the equation. Tracy had to help this student perform the traditional algorithm. After this student had “solved” the right expression, Tracy pointed out to the class that the first student had “added ninety to ten to get one hundred”. Tracy asked the class “did you understand how much easier it was to add your ninety to your ten to go ahead and get one hundred? Raise your hand if you understood that.” Most students raised their hands despite the use of the traditional algorithm in which ones and then tens were added. Tracy then reviewed the 1,000 activity again.

Tracy explained that the class had agreed to collect 1,000 Skittles in their ten jars and that they would be mapping their progress using charts. One student made a comment which reflected the financial situation for many of these students:

Student: I can’t bring any in because my mommy won’t spend money on candy.

[T]: Oh and that’s okay. Like I said before, it’s whatever you can bring in. If you can’t that’s fine.

The assistant teacher pointed out at this time that students could bring in the Skittles which they collect during Halloween. Some students asked some questions about this Class Collection Data Activity which Tracy addressed but most students had become restless again. Tracy then chose to move on to a worksheet that she had prepared which asked students to practice addition. Every student observed was applying the traditional addition algorithm, and this appeared to fit with Tracy’s expectations.

This lesson represented a classic example of a teacher transforming a reform-oriented activity into a traditional exercise of algorithm practice. Though Tracy posed the

Investigations problem as written, she only showed the traditional algorithm for addition and clearly expected students to use it. Several students were using graph paper to track the hundreds, but Tracy only showed the traditional algorithm and clearly expected the traditional algorithm. These students spent little time working together discussing approaches, especially when compared to the time they spent practicing the traditional algorithm on the worksheet. Tracy did not appear to recognize alternate approaches to this problem either. Instead, the problem became little more than a prompt for the algorithm. Further, Tracy incorrectly used the terms “solve”, “expression”, and “equation” when referring to the components of the equation posed to students. She also asked students if the equation “worked” instead of asking if it was true. No attempt was made to ask students to explain why the traditional algorithm worked. Of interest, Tracy summarized that the student had added “ninety to ten” when in fact the student had added one to nine and had carried the one. Tracy seemed to struggle with utilizing inquiry in this lesson as well. She appeared committed to providing guidance and not directly answering students’ questions, and she seemed committed to not telling them what to do as well. However, Tracy seemed to lack the knowledge and experience to do otherwise.

To confirm that a lack of teacher knowledge was at the root of Tracy’s failure to implement this lesson in a reform-oriented fashion, the Teacher Knowledge Test (Appendix A) was examined. There were two problems, #10 and #13, which dealt directly with assessing teachers’ understanding of non-traditional algorithms. Tracy missed both of these questions on the pre- and post-test. It seemed evident that Tracy’s knowledge and previous experiences with mathematics strongly impacted her teaching of this lesson despite her adamant commitment to teacher mathematics in ways that were different than those to which she'd been exposed. It also seemed as if the overall restlessness of these students and classroom management may have impacted Tracy's instructional decision-making. It is also noteworthy that Tracy never considered that students might have difficulty obtaining Skittles for the collecting 1,000 activity. The vast majority of her students are on free or reduced lunch, and the school even offers free breakfast to students through their relationship with a local church. For families struggling with the economic difficulties posed in 2009-2010, purchasing Skittles would seem to be a rather unnecessary expense, especially since the Skittles were not going to be consumed. However, in developing this activity, obtaining candy like Skittles was assumed to be an easy thing for a third grader. The economic backgrounds and experiences of these teachers were radically different from the economic realities for some of these students.

Observation #2. The second observation occurred in early December, and the lesson began with the same type of clock problem introduction used by Stephanie. Of note, Tracy utilized inquiry much as Stephanie had during this portion of the lesson. Tracy then moved on to the *Investigations* lesson by asking students to put away their clocks and open their notebooks. Tracy made a significant show of praising her students for making this transition quickly and posed a question about a basketball player who is 82 inches tall and a teacher who is 67 inches tall. "How much taller is the basketball player?" Tracy immediately mentioned using number lines, and every student observed made a number line with the number 52 as the first number from left to right. Tracy asked a student who had obtained the correct response to walk her through the response. Tracy remained in front of the class at the board while the student explained from their seat that they had created a number line and put 67 and 82 on it. Tracy drew a number line on the board and put 67 on the far left and 82 on the far right. However, Tracy also located 70 and 80 on her number line to scale but made no mention to students about why she located these values where she did. The student explained that she “subtracted 82 minus 67 by counting on the number line”. Tracy asked students how they would express this as an equation but then immediately wrote on the board “82 - ____ = 67” and “67 + ____ = 82” and asked students to fill in the blanks.

Tracy then posed a second question. “Phillip is 52inches tall. How much would he have to grow to be as tall as the basketball player?” She gave students time to work in groups on this second problem, and the researcher focused his observations on two students who seemed to be working on the problem together well. The two students were discussing several different methods of solving the problem using the number line. When prompted by the researcher to explain different ways of solving it, the girls showed how to count from 52 to 67 on the number line by counting by one’s or by two’s. One of them explained the traditional algorithm for adding 30 to 52 and stated that "it's easier to add 3 and 5" vertically, but this student failed to indicate any understanding of place. They also showed counting by ten and then counting five more. When referencing the first problem, one student showed counting by ones with unit markings on the number line from 70 to 80 and then counting by two’s from 80 to 82 because she “hadn't counted by ones on the number line in awhile". However, she had not scaled her number line as Tracy did and had left a disproportionately large gap between 70 and 80 relative to the gap between 60 and 70. It’s possible that the student marked ones from 70 to 80 because doing so allowed the student to consume the extra length. When asked about working together like they were, these two girls commented that they liked it that they were able to work together in their classes. They specifically commented that they were able to “help each other”. Tracy then asked a different student to come to the board and show how she had done the second problem. Tracy had obviously noted that this student had used a nice approach. The student drew a number line and counted from 52 to 82 by counting eight, then two tens, and then two ones. The student showed this addition using the tradition algorithm, and Tracy noted “how easy it was to add vertically”. Tracy then called on the young lady who had explained her work to the researcher. The student drew her number line on the board and showed the unit marks from 70 to 80. Tracy asked the student why she had counted by ones, and the student reiterated that she was practicing. Tracy finished the lesson by asking students to raise their hands if they knew what “how many more” meant and if they felt comfortable using the number line for addition and subtraction. All of the students raised their hands.

During the lesson, Tracy demonstrated strong and weak use of inquiry. During the clock problem introduction, Tracy strictly posed questions just as Stephanie had. Though the researcher never observed this team discussing these clock problem introductions, the similar uses of inquiry demonstrated by Tracy and Stephanie lead the researcher to conclude that the team had specifically discussed how to use inquiry with these problems. And though Tracy did a better job of asking students to explain their thinking, she still remained in front of the classroom and ‘showed’ her students how to use the number line to solve the first problem. It seemed obvious that students were mimicking Tracy’s use of the number line, and she may not have been aware of the importance of scaling her number line. The issue presented itself again when she asked a student to show her number line for the second problem on the board, but Tracy failed to seize upon that opportunity as well. It also appeared that classroom management was still at the forefront on Tracy's concerns. However, the comments made by the two students regarding the expectation of group work inherent in a PLC revealed a very positive reaction to what the students described as consistent opportunities to work in groups and "help each other". As was the case with the first observation, Tracy appeared to implement some of the reform-oriented practices to which she claimed to subscribe while implementation in other areas seemed restricted by her knowledge, previous experiences, desire to remain on pace maintain control of the class. Of note, the school wide commitment to making group work routine greatly supported Tracy's attempts to implement student group discourse as did the assumed team work regarding the use of inquiry throughout the introductory clock problem.

Observation #3. The third observation occurred in early January. Prior to the lesson, Tracy briefly discussed the *Investigations* lesson she was implementing with the researcher. The lesson was clearly designed to introduce the array as a model for multiplication while also covering the concepts of factors, primes numbers, and divisibility. The lesson was designed for students to recognize that 12 chairs could be arranged as one row of twelve, two rows of six, three rows of four, etc. but not evenly into rows of five, seven, eight, nine, ten, or eleven chairs. A brief examination of the lesson and discussion with Tracy made it seem as if the goals of the lesson were evident and direct. However, this particular lesson appeared to completely break down due to Tracy's understanding of multiplication, a possible view of multiplication in terms of multiplication tables or algorithms, and her need to manage her classroom and stay on pace.

Tracy began by asking each student to obtain 12 cubes; these were the Unifix cubes. Tracy explained that the 12 cubes represented chairs for students to arrange for the audience of a play. Tracy then expressed that students were tasked with determining the number of ways the chairs could be arranged. It took quite some time for students to acquire their twelve cubes and listen to Tracy's introduction. The researcher noted at this point that the assistant teacher had distracted students by twirling her keys while she walked around the room during Tracy's explanation. Earlier, the assistant had mentioned the possibility that snow might cause school to be canceled which naturally led to quite the eruption of student discussion. Some of these distracting behaviors on the part of the assistant had been observed previously, but mention is made here because Tracy had indicated the importance of "the lesson going as planned" as an indicator of a successful lesson, and she had also indicated having concerns about maintaining classroom discipline. Since these issues were at the forefront of Tracy's mind, special note was made of factors that might contribute to this problem. It seemed to take an inordinate amount of time to get the lesson started; a full ten minutes. However, students did ultimately start creating various arrangements of their cubes which Tracy asked them to record in their journals. Some of the students were working alone while others were working together. Some seemed to be strictly playing with the cubes. Tracy and the assistant were walking around the classroom making sure that students understood the goal and keeping them focused.

After about five minutes, Tracy asked some students to share their arrangements. It did take some effort to get the class settled down. Instead of having students draw their arrangements on the board, Tracy had students state how they arranged the chairs while she wrote on the board. This choice played a significant role throughout the remainder of the lesson as Tracy wrote up each arrangement in a particular way. When a student would say "I had one row of 12 chairs", Tracy wrote "1 row X 12 chairs = 12" and said "times" as she wrote "X". A second students stated "4 rows of 3 chairs", and Tracy wrote "4 rows X 3 Chairs = 12" while saying "four rows times 3 chairs equals twelve". At this point, Tracy reviewed that the rows were the horizontal lines of chairs. She did not introduce the term column at this time. "Now let's make three rows of four chairs". Tracy went on to draw a 3X4 array and a 2X6 array. She then asked the students what the vertical lines were called. A few knew they were called columns. Tracy continued to write the statements as multiplication on the board, but she had now dropped the words and instead appeared to be writing out multiplication tables. Tracy modeled how to translate "2X6=12" into a two by six array, and then asked students to represent "3X4" in their journals. By this point in the lesson, the researcher felt that Tracy had completely transformed the goal of this lesson to focus strictly on having students follow her modeling of representing a product as an array of rows and columns. It also seemed obvious that Tracy was preoccupied with maintaining discipline. The lesson ended without Tracy doing the 10-minute math review that she had planned.

Prior to this lesson, the researcher felt that Tracy had a clear understanding of the goal of this lesson regarding the development of number sense inherent in having students create arrays. However, Tracy appeared to refocus this lesson strictly on having students represent products as arrays. Though there was no time for a post-lesson interview, the researcher did have the opportunity to ask the entire team if they had introduced the term ‘column’. None of the other teachers had, and the researcher conveyed to Tracy that doing so appeared to deflect the lesson goal. Since Tracy’s view and understanding of multiplication appeared to play a role in her teaching of this lesson, the researcher examined Tracy’s responses on the pre- and post-Teacher Knowledge Assessments (Appendix A). Problems 7a, 7d, 8, and 12 on the assessment all dealt specifically with teachers’ understanding of multiplication. On the pre-test, Tracy answered 7a correctly but missed the other three, and she missed all four on the post-test. This lack of teacher knowledge and lack of experience with this particular *Investigations* lesson both appeared to have contributed to a drastic transformation of lesson goals. It also appeared that Tracy’s drive to remain on pace and maintain class discipline inhibited any chance of focusing on student thinking. A final failure in the eyes of the researcher was that, even though the researcher pressed reflection on this lesson during the planning session which occurred immediately after each teacher had taught this same lesson, the team’s discussion of this lesson was perfunctory at best. The team asked if they thought the lesson went well, and everyone said they thought it did but that they did not have enough time. That was the end of the discussion beyond the researcher’s questioning of the use of the term ‘column’. Even though this lesson contrasted with Tracy’s experiences learning mathematics, every other component of the experimental view toward teaching was grossly neglected. She failed to implement the lesson in ways that contrasted with her experiences. She failed to focus on student thinking. And she failed to reflect adequately on the lesson. In this situation, not utilizing an experimental view toward teaching could help explain why Tracy appeared not to grow from this lesson.

Observation #4. There was a large gap due to various scheduling issues between the third and fourth observations of Tracy. The third observation occurred in January while the fourth observation occurred in April. Though the researcher was not fully aware of some of the issues that Tracy had dealt with during that interim, this final observation became quite revealing. The researcher had arranged to observe Tracy teaching a final, culminating lesson on measurement and capacity. This lesson was chosen in an effort to provide follow-up on the lesson which Stephanie had taught. The hope was that the similarities and differences between Stephanie's practices and Tracy's practice would provide valuable information. While checking in at the front desk for the observation, the researcher was informed that Tracy and another 3rd grade team member would be exchanging rooms for the lesson that day. The researcher reported to the new room, but the exchange had not occurred yet. After waiting for a few minutes and observing one of Tracy's team members teaching the culminating lesson on measurement and capacity, the researcher went to Tracy's room to insure she was not teaching the lesson there. Tracy was not teaching but had just started an assessment. The researcher checked in with Tracy regarding the plans for that day and found out that they had changed and that Tracy was now assessing for the reminder of the lesson time. Though missing out on the intended observation was unfortunate, the revelations that emerged would prove significant.

Tracy's students were taking a practice end of grade assessment, and the researcher chose to use the change in plans as an opportunity to observe Tracy using the assessment materials that were supposed to play a crucial role in a PLC. An important flaw in the use of assessment tools made itself apparent. Tracy’s colleague, who will be called Sara, entered the room and announced that only two of her students had answered one of the trickier questions correctly. Sara began to peruse Tracy’s students’ work to see how they had done. Most of Tracy’s students had missed the problem as well, but one of them had put the correct response. “You are the MAN!” Sara stated as she then went on to identify students who were “caught” by that problem. The problem featured a pencil which was drawn just below a ruler. The eraser was positioned below the four inch mark on the pencil while the tip was positioned below the eight inch mark. Most of the students had indicted that the length was eight inches rather than the four inches. However, the student which Sara had praised had obtained the right answer to the problem. At this point the research sat with 'the man’ and asked him how he obtained his response. The researcher was trying to model inquiry for Tracy as a method for revealing the students' thinking. Though it was not the intent, the researcher actually revealed that the students' reasoning had been completely wrong. The student explained that he had selected the four inch length, not based on the difference between the eight and four inch marks on the ruler, but rather because the eraser was at the four inch mark. The researcher asked a follow-up question by drawing a second pencil above the ruler from the five inch mark to the eight inch mark. The student used the same reasoning and concluded that this shorter pencil had the greater length of five inches. Tracy and the researcher finished this segment of the interview by highlighting the importance of designing assessment questions well. The researcher also pointed out the danger in emphasizing multiple choice test results over the examination of student thinking.

When Tracy had initially learned that the other third grade teacher and she were not assessing at the same time, she immediately left the room to check in with her colleague. She explained that she just wanted to make sure that “they (the third grade teachers) were all doing the same thing”. I had mentioned that the assistant principal had stepped into Sara’s classroom, and Tracy had been worried about being observed while doing something different than the other teachers. The researcher was able to discuss this issue with Tracy directly once the students had left the room.

[R]: Can you explain to me why that (finding out Sara was doing something different) stresses you out again?

[T]: Just because I know that that’s (Tracy doing what the other grade level teachers are doing) what they’re (the administrators) looking for from me. It’s a really big deal. I mean it’s make or break for me because I was called in on a meeting on the [date] and basically it was she (the principal) was not happy with the way the instruction was going here (in Tracy’s classroom) and, you know, she wanted these changes made so we just (researcher clarified that Tracy had met with the principal and apologized).

[T]: That’s okay. I’m very positive about it.

[R]: That certainly helps me understand why you’re stressed.

[T]: (laughing nervously) She (the principal) was just like ‘I don’t like what I see. This is the way it’s going to be and I meet with her and take all my stuff and I’m just like..uh (sighs), I don’t know.

[R]: Why do you think she’s uncomfortable with the instruction?

[T]: Because it wasn’t tight. And I knew…I felt I was doing great, but you know, when you can take a step back and look and see how someone else is viewing it…someone that, you know, knows…It explains why I stay 'til 6:30 and 7 o'clock at night and still feel like can't breathe the next day. You know. And it explains a LOT…So now I'm literally …I feel like this (her planner) is my bible right here. I feel like everyday my life is in this binder, and it has to go according to my plan or I feel like if they come in and see it's not …it's going to be the end of me (giggles).

[R]: I mean, really? Is your job in jeopardy?

[T]: I feel like it is. I feel like with the all the layoffs and everything, you can't be too confident. There's an abundance of great, great teachers out there….I've never had a supervisor be displeased with any work I've ever done. I mean everywhere I've ever been, but she was very frustrated and I was like scared. I mean it worries me! It worries me a lot. I don't want to let anybody down.

Earlier in the interview, Tracy had indicated that some other things that concerned her:

[R]: Would you mind telling me again about why you feel it's important that …

[T]: plan together?

[R]: Yeah.

[T]: Well, one, when we have the core and we know exactly what we're supposed to teach. It's like you said 'measurement'. And I think that when we branch off and do our own thing, we think about the needs of our students, and we try to meet those needs. And that's how we end up changing it. But on the same note, it scares me because I'm…I feel like I'm so reliant, and this being a new curriculum for me, upon my experienced 3rd grade teachers. I want to do what they're doing. And I know… I feel like the administration wants to see that we're all on the same page, even though our classes are clustered. I do feel that we need to all be doing the exact same thing, just with modifications. It scares me to know …I think I've planned for what we're supposed to be doing, but you know, I know that the expectation is for all of us to be on the same page. And I feel safer; us being on the same page. And that way, if something happens, (pause) I feel like we've done everything is...We've worked on the same page. We've done everything the same. We've made our modifications. If something happens, and...then I feel like, okay, there...we..we did what we're supposed to do.

[R]: So when you say 'if something were to happen', the big thing that could happen would be…

[T]: They would not pass the EOG.

[R]: The big fear for you? Right?

[T]: Yes, that is a big fear for me.

[R]: Is that they won't do as well as you would like?

[T]: Exactly.

[R]: Or specifically...

[T]: Pass. Yeah. It terrifies me because this year we didn't have the pre-test so there's no way really…I don't think there's a way for them, for us, to determine the grade for 3rd grade. Whereas last year, they had the pre-test, and we knew where they'd started and we could see how much they'd grown at the end. This year, I feel like it's pass or fail.

[R]: And why does it matter whether you can tell how much they've grown versus whether they pass or fail?

[T]: Even if they fail, if they've made growth, if they've made a year's growth or if they've made enough growth, I can tell …it's not a failure to me.

[T]: Because I had one student to come in and he was at first grade level, so if he's at the end of second grade level, it's not enough for me. I wanted him on third grade level, but if I can see that he's made growth, then I feel like I've done my job. But if I feel like they've made no growth, I feel like I've been a failure as a teacher. In 4th grade [the grade Tracy taught the previous year], you know, I was able to see where they started and where they ended. You know, as far as growth, and that made me feel better if they didn't necessarily pass the test. Made ME feel better. I just want them to be better prepared for the next grade.

[R]: You're describing what sounds like how you evaluate your own effectiveness as a teacher.

[T]: Yes.

[R]: Is that…

[T]: Yes. Yes, because I need to know what I need to do different. I need to know what I need to do different next year in order to, I guess, get them to pass the test. I don't think that it's necessary for all the students to pass the test…There are a lot of obstacles for students. I'm not a test-taker. I never was a great test-taker. And only on the grace of God did I pass Praxis II the first time. Praxis I, I did not because I could see the time. I knew what time and counting it down and panicking, and all that played a part. And I see test-taking anxiety with some of my students already. I don't feel that every student's going to pass the test. I don't feel like every student can because that's the BIG test. But if they've made growth, that's enough for me. If they've made ENOUGH growth.

[T]: We have a program called Success Maker II. Love it. It shows how they've (the students) progressed in the program, and a lot of my students have made at least a year's growth. They've done really well. And when I look at that...But I don't think that's going to be enough for state standards. They need to see their test.

[R]: Earlier you said that you were only interested in the end of grade test

[T]: I am

[R]: because it would give information about their growth but now you're saying that Success Maker is also giving you that information. So why do you care that much about the EOG?

[T]: Because the state cares about the EOG.

[R]: Is that connected to your pay or your…

[T]: I don't think so. But, you know, with the way the economy is and with so many teachers being laid off, I'm not saying that if all my students passed, I would still have a job but I feel that they would see that I've done my job.

The excerpts presented above were all essentially from three different portions of a single interview taking place over the course of about an hour. The statements which Tracy provided indicated that she was focused almost exclusively on doing what the other third grade teachers were doing. And yet she also stated that they should be doing different things to meet the needs of the students in their classrooms who had been grouped by ability. It would in fact seem incumbent upon teachers of classes grouped by ability to teach differently. Yet, Tracy had abandoned that belief at the direction of her principal. This decision was also clearly impacted by Tracy's financial situation. From previous informal conversation, Tracy had indicated that she had purchased a home just prior to the collapse of the housing bubble. Tracy felt as if she could not afford to lose her job. Tracy's inexperience with the third grade curriculum made her feel insecure and dependent on the other teachers on her team. Tracy knew her students had grown that year, and she indicated that she measured her successfulness as a teacher in terms of student growth. But even this very personal belief was impacted by the recession because the state was unable to afford pre-test that year. In this single interview session, Tracy revealed the broad array of factors that impacted her practices.

Tracy's End of Study Data

The excerpts which follow contain the portions of the end of study interview that were directly connected Tracy's meetings with her principal and the impact those experiences had on Tracy's planning, teaching, beliefs, and anxiety. During this portion of this interview, Tracy revealed the stress caused by the experience when asked to explain what that initial meeting with the principal was like…

[T]: It was really scary. I cried. Because I never…I've worked at companies before and I've never had any issues. I've always been like the one who supervisors come to "Hey, can you help so and so" and can you train this person.

[R]: You felt criticized?

[T]: Totally and I was, like, ugh. I felt kind of stripped away.

This portion of the interview which is documented to a far greater extent in the discussion section of the conclusion clearly reveals the impact that school policies and administrative decision-making can have on instruction.

[R]: And was she rough on you?

[T]: Yes.

[R]: Okay, and in what way was she rough on you?

[T]: Very direct. Very serious. To me, I was like "it's my job".

[R]: Was it like "Either fix this next week or you're fired" or…

[T]: It was more like, you know, I need to see this or beginning next year, I'll have to put you on an action plan. And I was like "what's an action plan?" I'd never even heard of one before.

[T]: (Something like this) had never happened to me in the whole eight years I was teaching and my eleven years in corporate.

[R]: So how did that impact your teaching after that?

[T]: I stayed longer at school. I mean I planned. Okay, I would go in at work and get there a little bit before eight and stay until about five. After that, I'd stay 'til 8 sometime 8:30 or 9 'clock at night planning, making sure that every detail that I had down was perfect. The way I typed it had to be worded perfect because everything I did was being turned in to her.

[R]: So you turned in all your lessons to [the principal]?

[T]: Yeah. That was the hardest, the most difficult thing to do is to get those plans there a week ahead of time because I still had to plan with my team, but the team would meet on Monday, Tuesday, Wednesday, Thursday and plan for the next week, but I would have to have my plans in and typed prior to that…Sometimes they wouldn't have plans down for Monday until they came in that Monday.

[R]: So now all of the sudden you're spending one, two, maybe three hours more every day at work. I mean, you just don't have that kind of free time sitting around. Wasn't that kind of hard?

[T]: Oh yeah. It was very stressful. I was very stressed April, May, and even going into the last week of school.

[T]: The biggest stress though was if I didn't have lesson plans because there were a couple of weeks where we didn't plan and I still had to turn in something. And I didn't know what to turn in, and so I would just sit and think, type out what I thought was going to happen but when I met with her what was in this block had to be exactly what I was doing. So when I was typing it, that was stressing me out because I was like, what happens if this changes?

[T]: That was another thing that was said in that meeting. If you plan and if you change it, then you need to immediately write that you changed it and why you changed it.

[R]: And that was the reflection component?

[T]: Yeah.

[T]: It was really stressful. I had no life outside of school…My whole world was nothing but school and planning and making sure I was ready.

[R]: So you're saying it made you a better teacher, but it sounds like that was at a pretty high cost?

[T]: Oh, yes, hm mmm. And I still worry. When I go back to school, I'm worried, but in talking to other people that that has happened to, I guess it's not…two, three years later, people still worry. I don't know. It also keeps me on my toes to be worried.

[R]: Tell me what it is you're worried about?

[T]: That I'm not going to do it right.

[R]: Why does that matter?

[T]: [The principal] made this statement at the end of year "I knew that you could be like this. You just weren't showing it."

[T]: I'm more laid back and I don't think you can always be like that with students.

[T]: I'm worried because I worry about everything. That's just how I am, but I'm also feeling the most positive and productive that I have ever felt as a teacher.

[R]: But you're also working a lot harder and you're stressed.

[T]: And I don't want to get to the point where I hate my job because I still love it. I was really tired of it at the end of the year last year. But I could see the end, and I could see the end result, and that made me feel positive.

[T]: I'll just be real honest. I'm very glad it happened.

But Tracy would qualify this statement by agreeing that she was glad it was over as well.

[T]: I felt my job was in jeopardy. I truly did. That scared me more than anything.

[R]: Did that provide more stress than anything else?

[T]: The stress of losing your job if you don't get it right added with the stress of staying and having deadlines that you weren't sure that you were going to be able to meet, and still meet what you did with your team. All of that together was just a really bad combination. But for me to lose my job, be single and have a mortgage. That really did concern me. And I've never been fired from a job before…Still in the back of your mind all of you think is "I could be unemployed and that's pretty serious." I don't want to lose my job. I really like being here. And not only that but I have incredible respect for [the principal].

[T]: I'm a whole mixture of emotions and feelings here.

Tracy went on to discuss how she had come to utilize reflection better:

[T]: Until I really started truly writing and reflecting on the lesson plans, it wasn't as, I mean I would love to pull out those binders and look at that. And even at the end of year, in thinking about this coming year, I just wish I would have written more last year about what I did, how I did it, what things would I change, what I wouldn't change. I don't know. Reflection just has not been as important to me until I utilized it in my classroom for myself.

[R]: So you feel like you have utilized reflection more in your classroom for yourself?

[T]: Yes.

[R]: To change your teaching?

[T]: Yes.

[R]: Because you said "reflection has definitely changed me as a teacher for the better", but it sounds like you're also saying that you didn't start doing that until a couple months ago?

[T]: I think I talked about what I needed to change. You know, when we would sit in planning meetings with other teachers: "How did this lesson go?" And I would reflect upon that but I wasn't writing anything down and journaling AS I was teaching. I think that the reflection that I did prior was more verbal and it was with my group: "Well, I don't feel this went well because..." or "This went well because..."

[T]: I think when I really started writing it down during the day as the thought hit, as it was actually happening, well you know. I don't know?

[R]: So you think writing down your reflective ideas was really important for you?

[T]: Yeah, because for me to just to speak it, it's just that way, but if I write it down, I have to re-read it when I go back into those lesson plans, and you know, it helped me the next week in planning and…

[R]: So you think reflecting is important?

[T]: Yes.

[R]: How come?

[T]: We grow through reflection. We understand ourselves better. I believe. I feel like it helped me get a better grasp, a direction. I guess a more targeted goal, direction in my career as a teacher and in my lessons for the students. It didn't help just one aspect of me. It helped a lot of parts…(pausing) Just thinking. Yeah, it's not just professional. It was personal. The benefit of actually writing it down and having that where I can read it. To remind myself of this and what I was thinking. I mean it really did. It gave me a more driven purpose I think.

[R]: So what kind of stuff would you ideally reflect on if you wanted to improve your teaching?

[T]: The way that I had written my lesson plans. How I had prepared for my lesson plans. The delivery of the lesson plans improved because I had more details. Preparation was better…I don't know. It's funny I say reflecting is really important and I have no idea what to say to that.

Overall, this study provided valuable information regarding the factors that impact the interaction between teacher beliefs and teachers' professional activities. The study failed to shed significant light on the impact of having an experimental view toward teaching on teacher change, but direction was provided for future research that could better investigate this issue. The contribution of the *CI Model* was significant as no model of teacher change currently exists which incorporates both psychological and sociological perspectives. Moreover, the findings from the study provide strong support for the efficacy of the model. Additionally, research studies were described that would demonstrate the efficacy of the model while also making strong contributions to the literature.

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APPENDIX A: TEACHER KNOWLEDGE TEST

LEARNING MATHEMATICS FOR TEACHING

Learning Mathematics for Teaching &
Study of Instructional Improvement
610 E. University, Suite 1600
University of Michigan, Ann Arbor
48109-1259

A04

INSTRUCTIONS

* Answer all questions in this booklet.

* In completing this questionnaire, you should not spend more than 1-2 minutes on any problem. If you are not sure what you think about a particular problem, please respond by selecting "I'm not sure."

*When you are done, return the survey to the appropriate individual.

SECTION 1: Your background and teaching

1. How often do the **students** in your mathematics class do the following?

	Never	Less than once a mont h	1-3 times per mont h	1-2 times per week	3-4 times per week	Every day
a. Listen to me present the definition of a term or the steps of a procedure.	1	2	3	4	5	6
b. Perform tasks requiring methods or ideas already introduced to them.	1	2	3	4	5	6
c. Assess a problem and choose a method to use from those already introduced to them.	1	2	3	4	5	6
d. Explain an answer or a solution method for a particular problem.	1	2	3	4	5	6
e. Analyze similarities and differences among representations, solutions, or methods.	1	2	3	4	5	6
f. Prove that a solution is valid or that a method works for all similar cases	1	2	3	4	5	6

2. a. Please indicate the total number of years you have taught:

__ 0-1 year
__ 2-4 years
__ 5-9 years
__ 10-15 years
__ 16-20 years
__ 21 years or more
__ I have never taught

b. Please indicate the grade(s) you presently teach <u>mathematics</u> to (mark ALL that apply):

__ Grades K-1
__ Grade 2
__ Grade 3
__ Grade 4
__ Grade 5
__ Grade 6
__ Grade 7 or higher
__ I do not presently teach mathematics

c. Please indicate grades you have <u>ever</u> taught mathematics to (mark ALL that apply):

__ Grades K-1
__ Grade 2
__ Grade 3
__ Grade 4
__ Grade 5
__ Grade 6
__ Grade 7 or higher
__ I have never taught mathematics

d. Please indicate your credential type:

__ Emergency
__ Waiver
__ Intern
__ Preliminary
__ Full/Clear

SECTION 2

1. Ms. Wilson's class is working in groups to decompose 391 into hundreds, tens, ones, and tenths. As she walks around, she sees groups have arrived at very different answers. Which of the following ways to represent 391 should she accept as correct? (Mark YES, NO, or I'M NOT SURE for each choice.)

	Yes	No	I'm not sure
a) 3 hundreds + 90 tens + 1 one	1	2	3
b) 2 hundreds + 19 tens + 1 one	1	2	3
c) 3 hundreds + 9 tens + 10 tenths	1	2	3
d) 39 tens + 1 one	1	2	3

2. During a discussion about prime numbers in Mr. Gee's class, Natalie asked whether or not 1 is a prime number. Mr. Gee attended a workshop where he learned about primes. What is the crucial issue for Mr. Gee to remember in order to explain this to her?

a) 1 is a prime number because a prime number is only divisible by 1 and itself.

b) Some definitions of primes include 1 and some do not.

c) 1 is not considered to be prime, because every number can be expressed uniquely as a product of prime numbers, and if 1 were prime, the factorization would not be unique.

d) 1 is not a prime because it is a perfect square and no other perfect squares are prime.

e) I'm not sure.

3. Mr. Lopez was attending a professional development program in mathematics. One day they worked on the following problem:

> A program that is four weeks long is split into two equal sessions. The program's first session has two instructors (Nina and Amy) and the program's other session has five instructors (Melly, Rosa, Angela, Timo and Jim). What proportion of the overall program does Jim teach if all the teachers in his session share the work equally?

Several groups came up with different answers. There was a lot of discussion and disagreement. Which answer below is correct? (Mark ONE answer.)

a) $\frac{4}{7}$

b) $\frac{2}{5}$

c) $\frac{1}{10}$

d) $\frac{1}{7}$

e) $\frac{1}{5}$

f) I'm not sure.

4. Mr. Siegel and Mrs. Valencia were scoring their students' work on the practice state mathematics exam. One open-ended question on the exam asked:

Write the number that is halfway between 1.1 and 1.11.

Mr. Siegel and Mrs. Valencia were interested to see the different answers students wrote. What should the teachers accept as correct? (Mark ONE answer.)

a) 1.05

b) 1.055

c) 1.105

d) 1.115

e) I'm not sure.

5. Mr. Lee asked his students to compare $\frac{5}{9}$ to $\frac{3}{7}$. Which of the following should he accept as a correct explanation? (Mark ONE answer.)

a) $\frac{5}{9}$ is greater than $\frac{3}{7}$ because 5 is greater than 3.

b) They are equal because each is missing four pieces from the whole.

c) They are equal because adding two to the numerator in $\frac{3}{7}$ and two to the denominator in $\frac{3}{7}$ produces $\frac{5}{9}$.

d) $\frac{3}{7}$ is greater because the pieces will be bigger.

e) $\frac{5}{9}$ is greater because it is more than one-half, while $\frac{3}{7}$ is less than one-half.

f) I'm not sure.

6. A group of Ms. Lee's students was following a set of directions to move a paper frog along a number line.

Their last direction took them to $\frac{1}{2}$. The next direction says:

Go $\frac{1}{3}$ of the way to $\frac{3}{4}$. What number will the frog land on?

The students disagreed about where the frog would land. Which answer should Ms. Lee accept as correct? (Mark ONE answer.)

a) 1/12

b) 2/3

c) 7/12

d) 5/6

e) 1/4

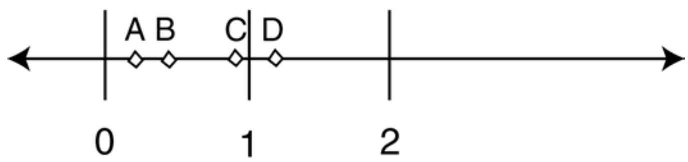
f) I'm not sure.

7. Teachers often offer students "rules of thumb" to help them remember particular mathematical ideas or procedures. Sometimes, however, these handy memory devices are not actually true, or they are not true for all numbers. For each of the following, decide whether it is true all of the time or not. (Mark TRUE FOR ALL NUMBERS, NOT ALWAYS TRUE, or I'M NOT SURE.)

	True for all numbers	Not always true	I'm not sure
a) If the first of two numbers is smaller than a second, and you add the same number to both, then the first sum is smaller than the second.	1	2	3
b) Multiplying a number makes it larger.	1	2	3
c) A negative number plus another negative number equals a negative number.	1	2	3
d) To multiply any number by 10, add a zero to the right of the number.	1	2	3

8. Mr. Stone is looking through some mathematics materials for some problems relating fractions to number lines. He comes across the following problem:

Which point is closest to $\frac{7}{16} \times \frac{1}{2}$?



He has not used number lines for this kind of problem before and he wants to make sure he is using it correctly. What is the intended answer to this problem? (Mark ONE answer.)

a) A

b) B

c) C

d) D

e) I'm not sure.

9. Mr. Lewis asked his students to divide $\frac{6}{8}$ by $\frac{1}{2}$. Charlie said, "I have an easy method, Mr. Lewis. I just divide numerators and denominators. I get $\frac{6}{4}$, which is correct." Mr. Lewis was not surprised by this as he had seen students do this before. What did he know? (Mark ONE answer.)

a) He knew that Charlie's <u>method</u> was wrong, even though he happened to get the right <u>answer</u> for this problem.

b) He knew that Charlie's <u>answer</u> was actually wrong.

c) He knew that Charlie's <u>method</u> was right, but that for many numbers this would produce a messy <u>answer</u>.

d) He knew that Charlie's <u>method</u> only works for some fractions.

e) I'm not sure.

10. As Mrs. Boyle was teaching subtraction one day, she noticed a few students subtracted in the following way:

$$\begin{array}{r} {}^{13} \\ 6\not{3} \\ -\,{}^{3}\not{2}8 \\ \hline 35 \end{array}$$

What were these students **most likely** doing? (Mark ONE answer.)

a) The students "subtracted up," by taking 3 away from 8, and then tried to compensate for this mistake.

b) The students compensated by subtracting 30 from 63, then dealt with the 8 and 3 in a second step.

c) The students made a mistake with the standard procedure, crossing out the 2 rather than the 6.

d) The students added ten to both 63 and 28, then subtracted.

e) I'm not sure.

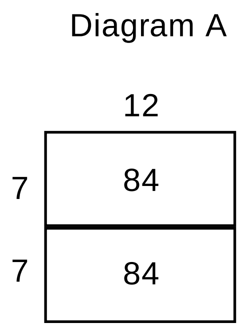
11. Ms. Lawrence is making up word problems for her students. She wants to write a word problem for $3 \div \frac{1}{2}$. Which word problem(s) can she include? (Mark YES, NO, or I'M NOT SURE for each problem.)

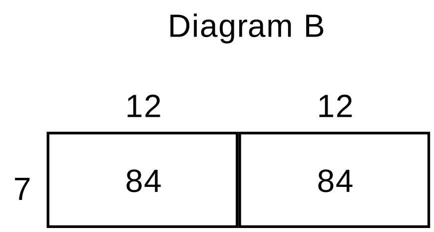
	Yes	No	I'm not sure
a) Melissa has 3 pizzas and she wants to give half of them to her friend. How much pizza will her friend get?	1	2	3
b) Dan has 3 cups of chocolate chips. He wants to bake cookies, and each batch requires $\frac{1}{2}$ cup of chocolate chips. How many batches of cookies can Dan make if he uses all of the chocolate chips?	1	2	3
c) Three friends each have half of a cookie. How many cookies would they have if they put them all together?	1	2	3
d) Jacquie has collected three cans of pennies for her fund-raiser. If she is halfway to her goal, how many cans of pennies had she set as the goal?	1	2	3

12. Luanne suggested the following method for multiplying 14 by 12:

> I know that 7 times 12 is 84, so to get 14 times 12, I double 84, which is 168.

Of the following diagrams, which BEST illustrates Luanne's method? (Mark ONE answer.)





a) Diagram A only

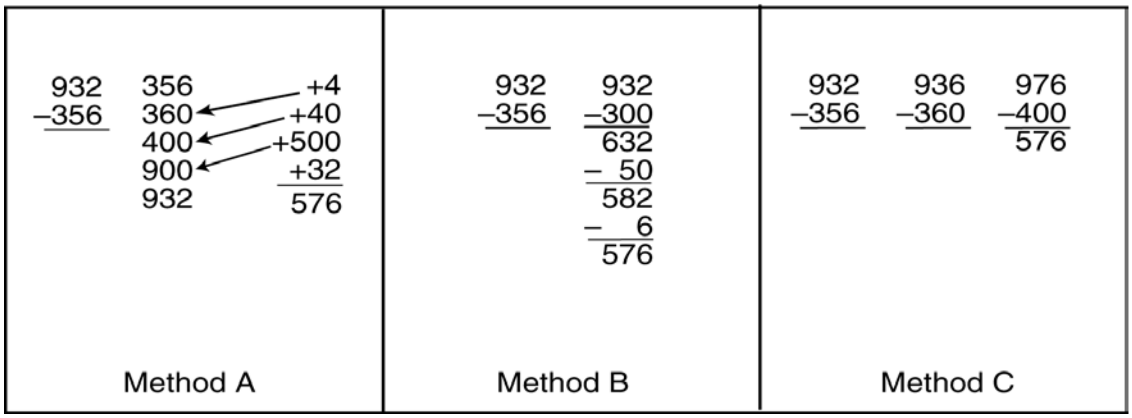
b) Diagram B only

c) Both diagrams represent Luanne's method equally well.

d) Neither diagram represents Luanne's method well.

e) I'm not sure.

13. Imagine that you are working with your class on subtracting large numbers. Among your students' papers, you notice that some have displayed their work in the following ways:



Which of these students is using a method that could be used to subtract any two whole numbers? (Mark ONE answer.)

a) A only

b) B only

c) A and B

d) B and C

e) A, B, and C

f) I'm not sure.

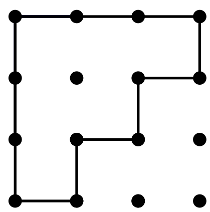
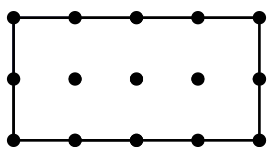
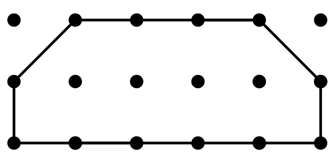
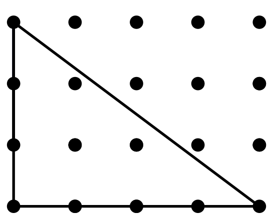
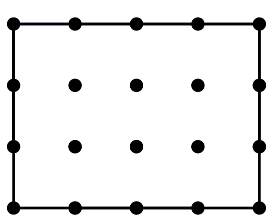
14. Mr. Nessbaum was teaching division with fractions to his class. "If we purchase 8 big chocolate bars from the school candy sale," he said, "and we want everyone in the class to have at least $\frac{2}{5}$ of a chocolate bar, do we have enough for our 25 students?" Mr. Nessbaum expected his students to write 8 divided by $\frac{2}{5} = 20$. Instead the students came up with several different approaches. Which of the students' approaches is valid? (Mark APPROACH IS VALID, APPROACH IS NOT VALID, or I'M NOT SURE for each.)

	Approach is valid	Approach is not valid	I'm not sure
a) After I cut each bar into five pieces, there are 40 pieces and everybody gets two. 40 divided by 2 equals 20, so we don't have enough.	1	2	3
b) There are 25 students. 25 times $\frac{2}{5}$ is 10 so we don't have enough.	1	2	3
c) You have to add $\frac{2}{5}$ twenty times to equal 8 whole chocolate bars. But that is not 25 times, so there are not enough pieces for everyone in our class.	1	2	3
d) There aren't enough because if I start with 8 and keep subtracting $\frac{2}{5}$, I get to zero before I have subtracted it 25 times.	1	2	3

15. Ms. Marcos' class was learning that in geometry there are often special cases, so that things may be true sometimes, but false other times. For each of the following statements, indicate whether it is always true, sometimes true, or never true. (Mark ALWAYS TRUE, SOMETIMES TRUE, NEVER TRUE, or I'M NOT SURE for each statement.)

	Always true	Sometimes true	Never true	I'm not sure
a) Triangles have three acute angles (acute angles are less than 90 degrees).	1	2	3	4
b) A rectangle is a square.	1	2	3	4
c) The area of a circle divided by the square of its radius is a little more than 3.	1	2	3	4
d) If a polygon has all its vertices on a circle, the area of the polygon is less than the area of the circle.	1	2	3	4
e) All of the angles of a hexagon are equal.	1	2	3	4

16. Mrs. Schlaff is using geoboards with her class (square grids of pegs at one unit intervals). The pegs on the geoboards she is using are spaced one inch apart. She asks her students to make figures with a perimeter of 12 inches. When she looks at what they are making, Mrs. Schlaff is concerned that some of their shapes do not have a perimeter of 12 inches. For each of the shapes below, determine whether the perimeter EQUALS 12 IN., DOES NOT EQUAL 12 IN., or if there is NOT ENOUGH INFORMATION to determine whether it equals 12 in.

		Perimeter equals 12 in.	Perimeter does not equal 12 in.	Not enough informati on	I'm not sure
a)		1	2	3	4
b)		1	2	3	4
c)		1	2	3	4
d)		1	2	3	4
e)		1	2	3	4

17. During a unit on geometry, Mr. Erikson asked his students to try to stump each other by describing figures that do not exist. Mr. Erikson compiled a list of their ideas and studied them to help him prepare for leading a class discussion the next day. Which of the following figures are possible, and which are impossible? (For each idea, mark POSSIBLE, IMPOSSIBLE, or I'M NOT SURE.)

	Possible	Impossible	I'm not sure
a) A rectangle that is not a parallelogram	1	2	3
b) A polygon with only two sides	1	2	3
c) A parallelogram with diagonals of equal lengths	1	2	3
d) An equilateral right triangle	1	2	3

18. Ms. Sanchez is playing "mystery shape" with her students, a game in which she gives her students clues for a shape she is hiding in her hand. Which set of clues has *square* as the <u>only</u> answer? (Mark ONE answer.)

a) I have four sides.
I have four right angles.

b) I have four sides.
I am not a parallelogram.
I have four equal angles.

c) I have four sides.
My opposite sides are parallel.
I can tessellate the plane.

d) I have four sides.
I have four lines of symmetry.

e) I am a regular polygon.
I have all congruent angles.

f) I'm not sure.

19. Mr. Nager writes the following statement on the board:

> The length and width of a rectangular swimming pool are each doubled, while the depth remains the same.

He asks his students to make mathematical statements about this pool. Which of the following student claims is true? (Mark ONE answer.)

a) It takes twice as much paint to paint the bottom.

b) It takes twice as much paint to paint the four walls.

c) It takes twice as much water to fill the pool.

d) All of the above.

e) None of the above.

f) I'm not sure.

20. Ms. Moreno finds the following definitions in a textbook:

> **Prism**: A solid figure that has two congruent, polygon-shaped bases, where all other faces are rectangles.
>
> **Pyramid**: A solid figure with a polygon base where all other faces are triangles that meet at a single vertex.

Thinking about the two definitions, Ms. Moreno wondered about the relationship between prisms and pyramids. According to these definitions, which of the following statements is true? (Mark ONE answer.)

a) A pyramid is a kind of prism.

b) A prism is a kind of pyramid.

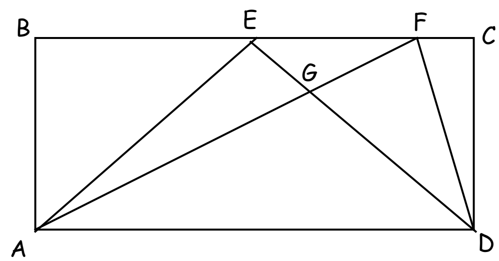
c) Some pyramids are prisms, but not all are.

d) No pyramids are prisms.

e) I'm not sure.

21. Mr. Juarez gave the following problem to his students:

ABCD is a rectangle. Compare the areas of triangles AED and AFD.



In the ensuing discussion, some of the students had conflicting ideas about the triangles' areas. Which of the following student arguments is correct? (Mark ONE answer.)

a) ΔAED and ΔAFD are congruent; therefore they have the same area.

b) The base and height of ΔAED and ΔAFD are the same; therefore they have the same area.

c) $\overline{AF}$ is longer than $\overline{AE}$; therefore the area of ΔAFD is greater than the area of ΔAED.

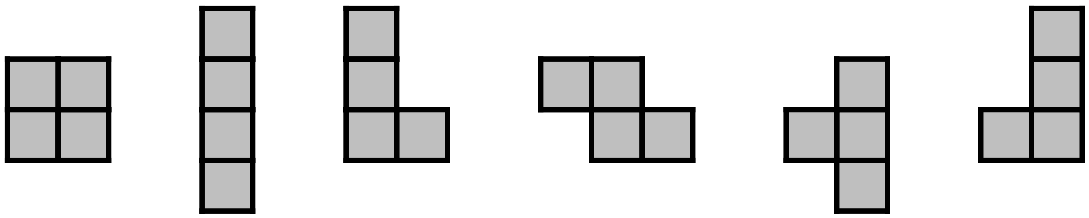
d) ΔAED has a greater area than ΔAFD because ΔAED is closer to the shape of an equilateral triangle.

e) Since ΔAED and ΔAFD share ΔAGD and since ΔAEG is obviously smaller than ΔDGF, then the area of ΔAFD has to be greater than the area of ΔAED.

f) You can't tell. The areas can't be determined without numbers.

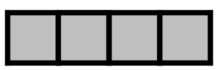
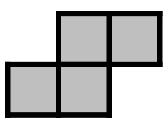
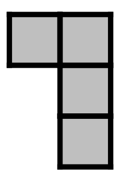
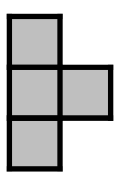
g) I'm not sure.

22. Ms. Markhill asked her students to write problems involving rotations in the plane. One of her students posed a challenging problem based on the Tetris video game.



Choose the shape below that, no matter how you rotate it, will not match any of the shapes above.

The class had some disagreement about what should be the correct answer. What should it be? (Mark ONE answer.)

a)	
b)	
c)	
d)	
e)	I'm not sure.

23. It was Sally's birthday. Mr. Siegel and Sally made up a math problem for the class:

> Sally is exactly twice as old as her brother. When will she be twice as old as him again?

The class generated the following ideas. Which of the following statements would you accept as correct? (Mark ONE answer.)

a) It will happen every two years.

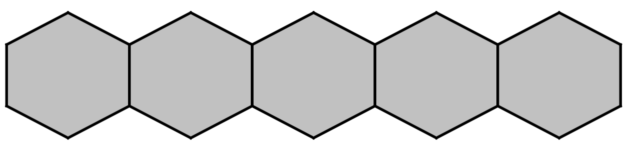
b) It depends on Sally's age.

c) It will happen when she is twice as old as she is now.

d) It will never happen again.

24. Ms. Jones was preparing to use the following task with her students:

> If you lined up 100 hexagons in a row
> this way, what would the perimeter be?



She knew how she would do it, but she wanted to anticipate what some of her students would come up with. Which of the following would work to find the correct answer? (Mark YES, NO, or I'M NOT SURE for each solution.)

	Yes	No	I'm not sure
a) 4 x 100 + 2	1	2	3
b) (6 x 100) – 2 x 99	1	2	3
c) 4 x 98 + 2 x 5	1	2	3
d) 6 x 100	1	2	3

25. Mr. Alder's students have been learning how to write equations to represent mathematical relationships. Last night, he assigned the following problem:

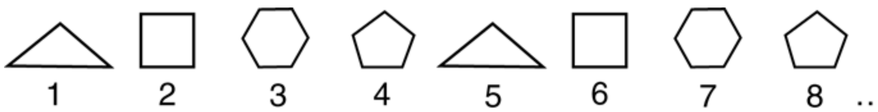
> A one-pound bag contains 50 percent more tan M&Ms than green ones. Write a mathematical statement that represents the relationship between the tan (t) and green (g) M&Ms, using t and g to represent the number of tan and green M&Ms.

He gets the following responses to the problem. Which responses represent the relationship appropriately? (Mark YES, NO or I'M NOT SURE for each response.)

	Yes	No	I'm not sure
a) $1.5t = g$	1	2	3
b) $.50t = g$	1	2	3
c) $.5g = t$	1	2	3
d) $g + \frac{1}{2}g = t$	1	2	3

26. Ms. Bourlin's new textbook has the following challenge problem:

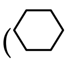
Look at the repeating pattern below. What shape would be 83^{rd} in the sequence?

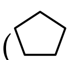


The new textbook does not include an answer to this problem, and Ms. Bourlin wants to make sure she knows it before she begins working on it with her class. What shape would be the 83^{rd} in this sequence? (Mark ONE answer.)

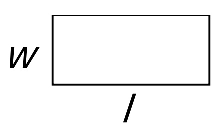
a) triangle ()

b) square ()

c) hexagon ()

d) pentagon ()

27. Mrs. Teva asked her students to write a formula for the perimeter of the rectangle pictured below. She was surprised by all the different answers students came up with. Which answer should she not accept as correct? (Mark ONE answer.)



a) $P = 2w + 2l$

b) $P = 2lw$

c) $P = 2(l + w)$

d) $P = l + w + l + w$

28. Mr. Jones used the following problem to develop his students' ability to write formulas to describe patterns:

> A row of squares can be made from toothpicks as follows:

> Write a formula to represent the number of toothpicks for any number of squares. Use *t* for the number of toothpicks and *s* for the number of squares.

Which of the following formulas represents the number of toothpicks (*t*) for a given number of squares (*s*)? (Mark ONE answer.)

a) $t = 4s$

b) $t = 3s + 4$

c) $t = 4s - (s - 2)$

d) $t = 2s + (s + 1)$

29. While working on different ways to represent linear functions, Ms. Hamid’s class got into a debate. Students put the following on the board.

I	II
 The first house has five toothpicks. The second has nine. Write a formula to show the number of toothpicks needed for the Nth house.	“Leah had one baseball card, and her brother gives her four cards every day. Show how many baseball cards she’d have on the Nth day.”
III 4N+1	**IV** N+4

Ms. Hamid’s students made different claims about which of the four represent the same linear function, where N = 1, 2, 3, …. Of the following statements, which BEST characterizes the relationships among these representations?

a) Each of these represents a different linear function.

b) Only I and IV represent the same function.

c) Only II and III represent the same function.

d) Only II and IV represent the same function.

e) Only I, II, and III represent the same function.

30. Ms. Ashton was teaching her students to represent situations with algebra. She wanted to create a story or context that would be appropriately modeled by the equation y = 2x + 3.

Of the following, which would be appropriately modeled by the equation y = 2x + 3, where x = 1, 2, 3, …?

	Yes	No	I'm not sure
a) Lu and her friends want to make birthday cards. They make 3 cards in September. Each month after that they make twice as many cards as the month before. How many cards have they made at the end of x months?	1	2	3
b) Joaquin earns $2.00 for each magazine he sells. Each time he sells a magazine he also gets a three-dollar tip. How much money will he earn after selling x magazines?	1	2	3
c) Earl starts with 3 baseball cards. Each week he gets 2 more baseball cards. How many cards does he have at the end of x weeks?	1	2	3
d) Kara is learning sign language. She starts by learning 5 signs on the first day. She learns 2 more each day. How many signs will Kara know after learning sign language for x days?	1	2	3

THANK YOU FOR PARTICIPATING IN THIS STUDY!

APPENDIX B: BELIEFS SURVEY

Teacher Beliefs Questionnaire

Teacher name: _______________________ Grade: ________

Indicate the degree to which you agree with each statement below by giving each statement a percentage so that the sum of the three percentages in each section is 100.

A. *Mathematics is:* Percents

1. A given body of knowledge and standard procedures; a set of universal truths and rules which need to be conveyed to students: _____

2. A creative subject in which the teacher should take a facilitating role, allowing students to create their own concepts and methods: _____

3. An interconnected body of ideas which the teacher and the student create together through discussion: _____

B. *Learning is:* Percents

1. An individual activity based on watching, listening and imitating until fluency is attained: ______

2. An individual activity based on practical exploration and reflection: ______

3. An interpersonal activity in which students are challenged and arrive at understanding through discussion: ______

C. *Teaching is:* Percents

1. Structuring a linear curriculum for the students; giving verbal explanations and checking that these have been understood through practice questions; correcting misunderstandings when students fail to grasp what is taught: ______

2. Assessing when a student is ready to learn; providing a stimulating environment to facilitate exploration; avoiding misunderstandings by the careful sequencing of experiences: ______

3. A non-linear dialogue between teacher and students in which meanings and connections are explored verbally where misunderstandings are made explicit and worked on: ______

This questionnaire was adapted from Swan, M. (2004). Designing and using research instruments to describe the beliefs and practices of mathematics teachers. *Research in Education, 75*, 58-70. Permit for use was obtained on May 29, 2009.

APPENDIX C: PRACTICES SURVEY

Teacher Practices Questionnaire

Teacher name: ________________________ Grade(s) taught: ________

Indicate the frequency with which you utilize each of the following practices in your teaching by placing an 'X' in the appropriate column.

#	Practice	Almost Never	Sometimes	Half the time	Most of the time	Almost Always
1.	Students learn through doing exercises.					
2.	Students work on their own, consulting a neighbor from time to time.					
3.	Students use only the methods I teach them.					
4.	Students start with easy questions and work up to harder questions.					
5.	Students choose which questions they tackle.					
6.	I encourage students to work more slowly.					
7.	Students compare different methods for doing questions.					
8.	I teach each topic from the beginning, assuming they don't have any prior knowledge of the topic.					
9.	I teach the whole class at once.					
10.	I try to cover everything in a topic.					
11.	I draw links between topics and move back and forth between topics.					
12.	I am surprised by the ideas that come up in a lesson.					
13.	I avoid students making mistakes by explaining things carefully first.					
14.	I tend to follow the textbook or worksheets closely.					
15.	Students learn through discussing their ideas.					
16.	Students work collaboratively in pairs or small groups.					
17.	Students invent their own methods.					
18.	I tell students which questions to tackle.					
19.	I only go through one method for doing each question.					
20.	I find out which parts students already understand and don't teach those parts.					
21.	I teach each student differently					

	according to individual needs.					
22.	I tend to teach each topic separately.					
23.	I know exactly which topics each lesson will contain.					
24.	I encourage students to make and discuss mistakes.					
25.	I jump between topics as the need arises.					

This questionnaire was adapted from Swan, M. (2004). Designing and using research instruments to describe the beliefs and practices of mathematics teachers. *Research in Education*, *75*, 58-70. Permit for use was obtained on May 29, 2009.

APPENDIX D: VIEW TOWARD TEACHING SURVEY

Name:

Indicate the degree to which you agree with each of the following statements:					
Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
It's important for me to improve my instructional practices:					
I would like my teaching to change as a result of participating in this program:					
My instructional lessons follow a typical format:					
I know my lessons are successful when:					
The students are thinking about the topic:					
We finish the lesson on time:					
We cover the topics scheduled for that lesson:					
The students focus on listening to what I'm saying:					
The students pay attention well:					
The students don't ask many questions:					
The students are well behaved:					
The students discuss related but different topics:					
The students are challenged:					

Indicate the frequency with which each of the following occur in your teaching:				
Statement	Almost Never	Rarely	Often	Almost Always
I alter previous lessons to try different things:				
I observe other teachers to see how they're teaching:				
I try to teach new lessons:				
I try new instructional methods:				
I only use instructional methods I'm confident with:				
I only use instructional methods that I know work well:				
After a lesson, I take some time to decide if the lesson went well:				
I change the way I teach based on:				
how engaged my students are:				
how well my students perform on assessments:				
feedback I receive from students:				
feedback I receive from colleagues:				
videos of myself teaching:				

APPENDIX E: INTERVIEW PROTOCOL

The questions below will be addressed during the baseline interview, post-observation interviews, intermediate interview, and/or the end of study interview. Ideally, all questions will be revisited until response consistency is obtained. The Experimental Teaching Model predicts that a teacher who adopts little to no experimental view toward teaching should demonstrate little to no changes in beliefs or practices. Subsequently, if a participant appear to have consistent beliefs and practices, then follow-up interviews will not be required. However, all participants will complete the final beliefs and practices survey and final interview.

- The perceived need to make instructional changes?
  - These questions will be addressed during the baseline interview:
    - Why are you participating in this professional development program?
    - In what ways are you expecting the program to alter your teaching?
    - Why do you want to develop in these areas?
  - These will be addressed during the baseline interview and during follow-up interviews.
    - Which aspects of your teaching are you hoping to develop?
    - What makes you believe you need to develop in these areas?
    - How will you know if you have developed in these areas?
- The type of planning used to prepare lessons?
  - These questions will be addressed during the observation interviews.
    - Which lesson did you choose to design? Is this a re-design of a previous lesson or a lesson designed to meet a new goal?
    - Why did you choose to design (re-design) this lesson plan?
    - What resources did you use to design/re-design this lesson?
    - How did you select the learning goal for this lesson?
    - Why is this learning goal important?
    - How does this learning goal align with national/NC curriculum standards?
    - In what ways does this learning goal differ from the learning goals you have had in previous lessons or other lessons?

The question sets below will all be addressed during the baseline interview and revisited during the observation interviews as needed.

- The degree to which experimental lessons challenge existing beliefs?
  - What is your typical lesson like?
  - What (which of the following) is your typical/ideal lesson script?
    - Why do you prefer that script?
    - Why do you believe that this script promotes learning?
    - What would make you re-think your opinion on the successfulness of this script?
    - Baseline Interview + follow-up observation interviews.
  - How does this lesson differ from your typical lesson/ideal script?

  - Why did you design this lesson to differ in this way?
  - Have you tried lessons similar to this type of lesson design before? If so, what were those experiences like?
- The type of 'evidence' used to determine the successfulness of a lesson?
  - How will you know if this lesson design 'worked well'?
  - What information will you use to ascertain the successfulness of the lesson?
  - Why do you think this information reveal the effectiveness of the lesson?
  - Why is it important for this lesson to be effective?
    - What will students get out of this lesson?
    - How will they use/need those outcomes?
- The type of reflection utilized after lessons? If reflection occurs.
  - How are you going to use the information of successfulness?
  - What are you going to do to learn from this lesson?
  - Are you going to examine student work? Discuss the lesson with students? Reflect on your observations? Utilize video to reflect on the lesson? Discuss the lesson with colleagues? Examine research in the area?
- The ways in which experiment 'conclusions' are applied to subsequent lessons?
  - How do you intend to use what you'll learn from this lesson?
  - What are you going to do if the lesson was particularly successful or unsuccessful?
  - What type of changes do you think you might make in the future if this lesson was particularly successful or unsuccessful?
  - Could the success of this lesson challenge your views toward teaching or learning?

The Beliefs Survey will be used as a reflective tool to engage teachers in discussing their beliefs towards mathematics, teaching, and learning. The teachers' responses to these survey questions will be re-visited during the Baseline, Intermediate, and End of Study Interviews as needed to identify the different ways in which the teachers' beliefs are change and why. If no changes appear to be occurring in a teacher's beliefs, then this component of the interviews will be dropped, though a final follow-up will occur for all participants during the final interview. Teachers will be shown how they would respond to these questions again and then shown how they responded previously. They will then be asked why those weightings altered (or failed to alter). Teachers might also be shown the graphic display of how their responses compare to those of other teachers (the results from the Swan (2008) study) in order to stimulate reflection and discussion.

Questions from Beliefs Survey:

D.	*Mathematics is:*	Percents
1.	A given body of knowledge and standard procedures; a set of universal truths and rules which need to be conveyed to students:	_____
2.	A creative subject in which the teacher should take a facilitating role, allowing students to create their own concepts and methods:	_____
3.	An interconnected body of ideas which the teacher and the student create together through discussion:	_____
E.	*Learning is:*	Percents
1.	An individual activity based on watching, listening and imitating until fluency is attained:	______
2.	An individual activity based on practical exploration and reflection:	______
3.	An interpersonal activity in which students are challenged and arrive at understanding through discussion:	______
F.	*Teaching is:*	Percents
1.	Structuring a linear curriculum for the students; giving verbal explanations and checking that these have been understood through practice questions; correcting misunderstandings when students fail to grasp what is taught:	______
2.	Assessing when a student is ready to learn; providing a stimulating environment to facilitate exploration; avoiding misunderstandings by the careful sequencing of experiences:	______
3.	A non-linear dialogue between teacher and students in which meanings and connections are explored verbally where misunderstandings are made explicit and worked on:	______